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Citation
Blair, Ann. "Natural Philosophy." In The Cambridge History of Science: Volume 3, Early Modern Science, edited by Katherine Park and Lorraine Daston, 365-405. Cambridge: Cambridge University Press, 2006.

Published Version
10.1017/CHOL9780521572446.018

manuscript for

Ann Blair, "Natural Philosophy" in The Cambridge History of Science, vol. 3: Early Modern Science, ed. Katharine Park and Lorraine Daston (Cambridge: Cambridge University Press, 2006), pp. 365-405.

Natural Philosophy

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“Natural philosophy” is often used by European historians as an umbrella term to designate the study of nature before it can easily be identified with what we call “science” today, to avoid the modern and potentially anachronistic connotations of that term. But “natural philosophy” (and its equivalents in different languages) was also an actor's category, a term commonly used throughout the early modern period and typically defined quite broadly as the study of natural bodies. As the central discipline dedicated to laying out the principles and causes of natural phenomena, natural philosophy underwent tremendous transformations during the early modern period. From its medieval form as a bookish Aristotelian discipline institutionalized in the universities, natural philosophy became increasingly associated during the sixteenth and seventeenth centuries with new authorities, new practices and new institutions, as is clear from the emergence of new expressions, such as the “experimental natural philosophy” of Robert Boyle (1627-91) and the Royal Society of London or the Mathematical principles of natural philosophy (Philosophiae naturalis principia mathematica, 1687) of Isaac Newton (1642-1727).[1]

Traditional natural philosophy (that is, of the bookish, largely Aristotelian, variety) continued to prevail in university teaching through much of the seventeenth century [See GRAFTON], but it too was transformed by the innovations of the period, which prompted attempts at adaptation as well as staunch resistance. By 1700 it had yielded definitively in all but the most conservative contexts to the mechanical, mathematized natural philosophies of Cartesianism and Newtonianism.[2] Nonetheless the term "natural philosophy" continued to be current (notably in English) through the eighteenth century, its broad scope left intact by the transitions to new methods and explanatory principles. The concept and the term were replaced starting in the early nineteenth century by the emergence and professionalization of specialized scientific disciplines, with which we are familiar today, from biology and zoology to chemistry and physics.[3]

The University Context of Natural Philosophy

"Philosophia naturalis" served as a translation of Aristotle's physikê êpistêmê and was also called "physica" or "physice" (a shortened version of the same expression).[4] It originally designated one of the three branches of speculative philosophy delineated by Aristotle, alongside mathematics and metaphysics.[5] As institutionalized in the universities of medieval Christendom, starting in the thirteenth century, natural philosophy consisted in the study of and commentary on Aristotle's libri naturales. These comprised (as in the regulations of Paris, 1255, equivalents of which prevailed in universities throughout Europe): Aristotle's Physics, On the Heavens, Meteorology, On the Soul, On Generation and Corruption, the History and Parts of Animals, the shorter works known collectively as the parva naturalia—including On Sleep and Waking, On Memory and Remembering, On Life and Death—and two tracts now considered of doubtful authenticity, On Causes and On Plants.[6] But, given the special emphasis on logic in the medieval curriculum, natural philosophy was generally reduced in practice to the study of the Physics on the one hand (with some consideration of On the Heavens and Meteorology) and On the Soul on the other (with some reference to the parva naturalia).[7] At the University of Paris for example, once Aristotle had become the centerpiece of the curriculum in the mid-thirteenth century, a candidate for a bachelor's degree took only a minimum of natural philosophy, and focused primarily on grammar and logic. Natural philosophy featured mostly in the two years of additional course work for the master's degree, which was required in order to teach or to continue on to a higher faculty (i.e., law, medicine, or theology).[8] Despite variations between institutions, some of which offered more instruction at the undergraduate level in the quadrivium (the mathematical disciplines of arithmetic, geometry, astronomy, and music), this basic pattern remained the norm in Europe until the end of the seventeenth century.

Broadly speaking, the institutional structures of the medieval universities remained in place throughout the early modern period. But the rapid expansion in higher education starting around 1500 and the new technology of printing fostered new pedagogical developments. Throughout Europe students attended universities in greater numbers in the sixteenth century; the dates at which attendance curves peaked varies from place to place, from around 1590 in Castile to 1660 in Louvain.[9] About 100 new universities were founded between 1500 and 1650 (while ten existing universities were abolished, transferred or merged in the same period). The new foundations were often associated with a religious offensive. In the first half of the sixteenth century they clustered in Spain, affirming the effects of the reconquista—that is, the "reconquest" of Spain from its Muslim and Jewish inhabitants. After the peace of Augsburg (1555) established the principle of religious territoriality (cujus regio, eius religio), new universities multiplied in the principalities of central and Eastern Europe, as each region needed schools appropriate to its ruler's religious choice.[10]

The growth of state bureaucracies also required more educated elites to fill them, prompting the formation of new educational institutions. These included the collèges de plein exercice at the University of Paris and the Jesuit colleges founded across Europe, which offered instruction independent of the faculty of arts that combined a secondary education in Latin and elementary Greek grammar and rhetoric, with two or more years of university-level work devoted to philosophy. Students could attend such colleges alongside or instead of university courses for the B.A., although degrees could only be conferred by the universities near which these colleges were often located.[11] Special schools also catered to the sons of the nobility (Ritterakademien in the Empire; collegi dei nobili in Italy; gymnasia illustria in the United Provinces; academies like that of Pluvinel in France).[12] Finally, the various religious orders and the secular clergy ran monastic schools and seminaries to train their members.

The general trend across Europe during the sixteenth century, under confessional and administrative pressures to educate more students faster (notably to serve as preachers and bureaucrats), was to compress subjects previously reserved for the later into the earlier years of study.[13] As a result more students were exposed to instruction in natural philosophy, notably for the B.A. This trend, combined with the spread of printing, fueled a great increase in the number and kinds of books of natural philosophy, particularly of the pedagogical variety.[14] For the professors there were numerous editions, translations, commentaries and specialized treatises, whether of the traditional scholastic or the newer humanist variety.[15] Humanist editions and translations strove to strip away the legacy of the medieval Arabic transmission in favor of a translation from the Greek original into elegant Ciceronian Latin. Humanists delved into the newly recovered Greek commentaries on Aristotle from late Antiquity, for example by Themistius (first published in Latin in 1481), Alexander of Aphrodisias (first published in Latin in 1495), or Simplicius (first published in Greek in 1499), but the medieval commentary of Averroes, a scholastic favorite, remained standard for many university professors.[16]

For students, aids to the acquisition of Aristotelian natural philosophy included Latin editions shorn of cumbersome commentaries, but instead enhanced with such trappings as summaries, dichotomous tables, and indexes. The genre of the philosophical textbook, which offered a succinct compendium or manual of natural philosophy, flourished in the sixteenth century.[17] Catholic textbooks were often structured around the traditional medieval quaestio, a question in "whether" (e.g., whether the world is eternal?) around which one gathered arguments, objections and responses to objections in favor of alternative solutions before reaching a conclusion.[18] Protestant textbooks, on the other hand, straying more readily from medieval practice and in imitation of Philip Melanchthon (1497-1560), who was the first to include Aristotle in the Lutheran curriculum, tended to pose simplified questions ("what is the world?") that called for definitions and descriptions rather than subtle argumentation, and might be answered by a series of numbered propositions.[19]

Most notorious for their pedagogical reductions of complex material were the Calvinist pedagogues who followed the French educational reformer Petrus Ramus (Pierre de La Ramée, 1515-72). They favored the use of dichotomous tables, from the disposition of which the student would supposedly be able to master any topic. For example, a textbook by Wilhelm Scribonius, already in its fourth edition in 1600, presented a vast topic like animals by providing the proper subdivisions of it without any descriptions or explanations. Scribonius divided animals into rational and irrational, the latter into those living in water and those on land, the land animals into reptiles and quadrupeds, the quadrupeds into oviparous and viviparous, the viviparous into those with cleft hooves and those with solid hooves, and so on.[20] Textbooks of these various kinds insured a broad diffusion among students of the basic elements of Aristotelian physics.

Although the flow of university texts, from theses and textbooks to commentaries and treatises, continued exclusively in Latin into the 18th century, the first vernacular textbooks of Aristotelian natural philosophy, starting in 1595, testified to the broadening of the audience seeking a university-style education. These books probably appealed to privately tutored noblemen, to students so weak in Latin that they needed a vernacular crib, to intellectually ambitious barber-surgeons or artisans (such as the potter Bernard Palissy, c. 1510-90), and to women, as one dedication suggests.[21] The authors of these works complained of the difficulty of their task, which required coining new vernacular terms, to match technical Latin ones, but they were no doubt proud, as one voluble French translator was, to satisfy the desires of "those very studious in French books ... who had often begged [him] to give them some book in French to attain knowledge of the secrets of nature" and in so doing to "enrich, embellish and adorn our language after the example of the ancients."[22] None of Aristotle's actual writings about nature were translated into vernaculars, however. A set of problems offering questions and answers about the human body and health circulated in the sixteenth and seventeenth centuries as the Problemata Aristotelis (Problems of Aristotle), in Latin and in German, French and English translations, but this text was composed in the Middle Ages and bore no relation to the ancient Problems now identified as pseudo-Aristotelian.[23] This work is representative of the most popular extension of Aristotelianism, alongside collections of sayings or short excerpts attributed to Aristotle that were also available in Latin and in the vernacular, such as Jacques Bouchereau's Flores Aristotelis (Flowers of Aristotle, first published 1560) or William Baldwin's Sayings of the Wise (first published 1547).[24]

The extent to which formal changes in the transmission of natural philosophy at the Renaissance universities made the discipline particularly more open to new ideas is debatable. The medieval quaestio, after all, lent itself perfectly well to departures from Aristotle's original concerns or arguments, although medieval authors tended to mask their innovations rather than point them out.[25] Renaissance commentaries certainly gave their authors a wide berth for innovation, allowing for digressive discussions that could stray from the initial passage or opinion at issue.[26] Textbooks, in which the author constructed a systematic presentation of his own, albeit within an Aristotelian framework, have been hailed as the "pedagogical expression of a serious revolution, that which gave birth to

Descartes."[27] Each of these forms offered opportunities for modifying the tradition even as they transmitted it.

Rather than singling out the Renaissance as a time of decadent or eclectic Aristotelianism, recent scholarship has emphasized the vitality and variety of Aristotelian philosophy throughout the nearly 500 years of its dominance (c. 1200-1690). Indeed there never was a period characterized by the spread or imposition of a monolithic interpretation of Aristotle. Medieval Aristotelianism had always embraced a wide range of positions, from Averroism to positions tinged with Platonism, such as those of Thomas Aquinas on the soul, to the nominalist probes of the limits of reason, in Scotism and Ockhamism; the quaestio itself as a form encouraged awareness of the multiplicity of possible arguments and solutions. In the analysis of the historian of science Edward Grant, flexibility was a central feature of Aristotelianism as a philosophical system and the key to its long survival. Aristotle's own obscurities and ambiguities precluded agreement on any one interpretation, so that variety of interpretation was perforce the norm. At the same time Aristotelian principles, with their near universal applicability, could be used to generate new theories and respond to new concerns (as in medieval theology, for example). Furthermore, the fact that natural philosophy was fragmented into hundreds of separate quaestiones (e.g., on Aristotle's Physics book IV: is place immobile? is the concave surface of the moon the natural place of fire? is every being in a place? is the existence of a vacuum possible? is a resisting medium required in the motion of bodies?) masked the inconsistencies generated by that flexibility and discouraged debate about the system as a whole.[28]

Aristotelian natural philosophy faced a number of challenges in the Renaissance, stemming from a new awareness of alternative ancient philosophies, the resurgence of religious objections, and recent empirical observations and discoveries, as I will describe below. But the result was hardly a turn away from Aristotle: as Charles Lohr pointed out, "the number of Latin Aristotle commentaries [in all fields] composed between 1500 and 1650 exceeds that of the entire millennium from Boethius to Pomponazzi."[29] Of all the areas to which commentaries on Aristotle could be devoted, natural philosophy was second only to logic in the number of commentaries produced; at least one third of all Aristotle commentators wrote on one or more aspects of natural philosophy—more than those who wrote on metaphysics, ethics, rhetoric or politics combined.[30] Printing and the expansion of higher education doubtlessly account for the explosive nature of this growth of Aristotelica.[31] But these figures are eloquent testimony to the fact that Aristotle was still <u>the</u> Philosopher to print, to teach, and to study.

Aristotle alone came complete with interpretive formulations finely honed over centuries of debate and reflection, which adapted his philosophy to the needs and concerns of Christian orthodoxy. Only for Aristotle did there already exist a vast arsenal of pedagogical presentations and tools suitable for students at various levels, on which professors could build without having to start from scratch. Finally, given its flexibility, Aristotelianism had the resources with which to respond to many of the new challenges. As a result these challenges generated more interpretations and adaptations, rather than a decline in Aristotelianism. Institutional and intellectual factors together can account for the continued vitality and increased productivity of Aristotelian natural philosophy through the first half of the seventeenth century. Aristotelianism remained the common philosophical ground of the Renaissance, the point of reference in relation to which every new philosophy had to prove its tenability.[32]

Aristotelianism and the Innovations of the Renaissance

Charles Schmitt has outlined two different kinds of eclecticism, or openness to innovation, evident in Aristotelian natural philosophy. The first, already present in the Middle Ages, was an openness to new developments that emerged within the tradition. The second involved a willingness to draw on sources outside that tradition and was a specific characteristic of Aristotelianism in the early modern period.[33] In the first instance, the universities of the Renaissance inherited the full range of Aristotelian positions found in the Middle Ages, displaying plenty of internal eclecticism: Thomists and Scotists were widespread throughout Europe; Italian universities were known for their Averroists; in Germany there were also Albertists; at the University of Krakow in the sixteenth century Aristotle was "still read with the eyes of John Buridan," while in early sixteenth-century Paris Spanish scholars like Juan de Celaya (1490-1558) and Luis Coronel (d. 1531) followed the calculatory tradition of fourteenth-century Oxford.[34] Not only were there disagreements between these scholastic “sects,” but there were equally important disagreements within them, because of the variety of ways of being a “Thomist” or an “Averroist.”[35]

In addition, during the Renaissance, Aristotelian natural philosophers faced a number of new challenges, which originated outside the universities and outside the Aristotelian tradition—from the humanists and the newly recovered ancient sources they made available, from the Protestant and Catholic Reformations and their concern to make philosophy better serve religion, and from the emergence of new empirical observations and mathematical methods. The responses of Aristotelian natural philosophers ranged from the selective adoption of certain innovations to conservative defenses of received opinion.

The humanists fostered the study of a “new Aristotle” based on new, more elegant Latin translations (e.g., by Leonardo Bruni [1369-1444] and Theodore Gaza [1400-76]), a new emphasis on Aristotle’s ethical and political writings, and newly recovered ancient commentaries (by Themistius or Simplicius for example). Italian humanists also revived a number of other ancient philosophical authorities, including Plato and Hermes Trismegistus, the legendary Egyptian priest, Epicurus and the skeptic Sextus Empiricus. Although various works of Plato, including the

Timaeus, with its account of the origins of the world, had been available in Latin in the Middle Ages, the arrival of Byzantine émigrés in fifteenth-century Italy gave a new seriousness to the study of Plato as a philosopher. Georgios Gemistos Pletho (c. 1360-1454) was exceptional in promoting Plato with the idea of rebuilding the polytheistic paganism of ancient Greece.[36] Most humanists valued Plato instead as a buttress to Christianity, and adduced in support of this interpretation the writings of the Neoplatonists, especially Plotinus (205-269/70) and Proclus (c. 410-85). Early proponents of Plato did not necessarily attack Aristotle. Although George of Trebizond framed his Comparatio Platonis et Aristotelis (Comparison of Plato and Aristotle, 1458) as a preemptive defense of Aristotle against the Platonists, other humanists attempted to reconcile the two, following the Byzantine position that the two philosophers were fundamentally in agreement.[37]

The Florentine philosopher Marsilio Ficino (1433-99) was the first to develop Platonism into a system complete enough to rival Aristotle's. Ficino composed voluminous translations of and commentaries on Plato and the hermetic texts and offered his own synthesis of Christianity and Platonism in his Theologia platonica (composed around 1474, published in 1482). He contrasted this "pious philosophy" with what he considered the impieties of scholastic Aristotelianism.[38] Defenders of Plato maintained that Plato's belief in individual immortality and in the creation of the world by a divine Demiurge made his philosophy more easily reconciled with Christianity, but critics noted the difficulties posed by Plato's belief in the transmigration of souls and by the fact that the creation described in the Timaeus was not a creation ex nihilo, but rather from pre-existing matter. Platonism found support here and there throughout the early modern period, for example among German mystics, from Nicholas of Cusa (1401-64) to Jakob Boehme (1575-1624); or from isolated individuals like Symphorien Champier (c. 1470-1539) in France and Leo Ebreo (c. 1460-1523) in Portugal, down to Henry More (1614-87) and Ralph Cudworth (1617-88), who as fellows at Cambridge used Platonism to combat materialist interpretations of the new mechanical philosophy.[39] Only in Italian universities were a few professorships created for the teaching of Platonism alongside the usual Aristotelianism: in Pisa (1576), Ferrara (1578), and Rome (1592), the latter two having been created for Francesco Patrizi (1529-97) in particular.[40]

The impact of Renaissance Platonism and Hermeticism on scientific developments has been much debated. Frances Yates argued that the Neoplatonist emphasis on the successive emanations from a perfect being to lower and lower orders of existence helped inspire enthusiasm for heliocentrism, which placed the sun at the center of vital emanations of heat and light.[41] [See COPENHAVER] But most thinkers inspired by Platonism or Hermeticism remained hostile to Copernicanism.[42] The notable exceptions, Giordano Bruno (1548-1600) and Johannes Kepler (1571-1630), each also had other motivations for their choice of heliocentrism. Bruno embraced Copernicanism in the context of an infinitist cosmology, which he justified as a tribute to divine omnipotence, free from the standard cosmological and physical assumptions.[43] Johannes Kepler hailed Copernicanism as mathematically superior because it established the order of and distance between the planets and aided him in his goal of elucidating the geometrical or musical harmonies present in these relationships.[44] The impact of Platonism on Galileo has long been a matter of debate; recent work has emphasized the need to consider, in this controversy, how Platonism was understood in the Renaissance rather than in our time.[45] At this point, Platonism can plausibly be credited with fostering a renewed interest in geometrical-mathematical methods, which a few Italian professors of philosophy hailed as a replacement of the dry logicism of Aristotle.[46] In addition, Platonism offered one of the first viable alternatives to Aristotelian natural philosophy and helped to challenge some of its specific assumptions, including, for example, the Aristotelian notion of the quintessence, a fifth element peculiar to the superlunary world that distinguished it from the sub-lunary.[47]

Other philosophical alternatives to both Aristotle and Plato were brought to light by humanist discoveries of long-lost manuscripts. Ancient atomism, for example, was first revived with the discovery in 1417 by Poggio Bracciolini of a manuscript of Lucretius' <u>De natura rerum</u> (<u>On the nature of things</u>) in the library of a Swiss monastery. The translation by Ambrogio Traversari of Diogenes Laertius' <u>Lives of Eminent Philosophers</u> (first published in 1533) gave a new currency to the opinions of many ancient figures, including Epicurus, who had long been dismissed as a mere libertine.[48] The Stoics too were proposed, notably by Justus Lipsius (1547-1606), as offering an alternative and more pious natural and moral philosophy than Aristotelianism.[49] The Presocratics and the Pythagoreans also appealed, especially to philosophers in the Platonic vein.

Hostility to Aristotle was especially widespread among a group of late-sixteenth-century Italian philosophers often called "nature philosophers" because of their emphasis on natural philosophy.[50] [see GARBER] Although innovative, their philosophies remained speculative, without empirical or mathematical components, and were stymied by the Counter-Reformation Church, which exhibited a preference for Aristotle and the Thomist synthesis after the Council of Trent (1545-63).[51] Among the earliest of these critics of Aristotle was the Italian physician and polymath Girolamo Cardano (1501-76) who, for example, reduced Aristotle's four elements to three by eliminating fire as an element. Despite incurring an accusation of heresy for casting a horoscope of Christ in 1570 and a scathing attack by Julius Caesar Scaliger in defense of Aristotle, Cardano acquired an international reputation for his books of natural philosophy as well as his practice of medicine and astrology.[52] Francesco Patrizi developed a more systematic new philosophy to replace Aristotelianism in his Nova de universis philosophia (New Philosophy of the Universe, 1591), which relied on Platonic sources to portray God as an incorporeal, intellectual light, who pours forth light and heat to create the world, generating successively lower and lower levels of being. Despite the initial favor of pope Clement VIII, the book was placed on the Index of Forbidden Books in 1594; Patrizi continued to teach Platonic philosophy, first in Ferrara then in Rome, until his death in 1597, but at that point the papal theologian Robert Bellarmine, who as cardinal would later take a stern line against Galileo, concluded that Platonism was more dangerous to Christianity than Aristotelianism and recommended that his chair of Platonic philosophy be suppressed.[53]

Offering yet another alternative to received philosophy, Bernardino Telesio (1509-88) rejected Aristotelianism on the grounds that it was in conflict with the senses and with Scripture and instead explained the natural world as the interaction between the two principles of hot and cold. In order to Christianize this revival of pre-Socratic naturalism, he introduced a universal spirit (also reminiscent of Stoic pneuma), which infused the world and from which he drew new definitions of time and space. Telesio's works were condemned posthumously in 1593.[54] Tommaso Campanella (1568-1639), a disciple of Telesio, carried the idea of the world-spirit to the extreme of envisioning the whole universe as a living animal in which God was omnipresent and immanent (“pansensism”). Nature was full of correspondences and divine messages that the natural philosopher could interpret, especially through astrology. Imprisoned in 1599 for fomenting rebellion in Calabria against Spanish domination there, Campanella spent most of the next 30 years in jails; he was released in 1629 by pope Urban VIII and practiced astral magic with him to ward off evil celestial influences, and when Spain threatened to have him extradited, he fled to France in 1634. He had the support there of a circle of "libertine" philosophers, who increasingly became disillusioned with his querulous demands for greater recognition.[55] Finally, Giordano Bruno (1548-1600), drawing on a wide range of sources including the atomist Lucretius, his contemporary Telesio and Neoplatonists like Plotinus and Nicholas of Cusa, suggested that all matter is infused by soul.[56] Rather than proposing a pious philosophy, like that of Ficino however, his solution was to subsume religion under a rationalistic worldview and it was probably this naturalism rather than any particular aspect of his theories (such as Copernicanism) that led to his being burnt at the stake for heresy in 1600.[57]

Although these Italian nature philosophers did not succeed in unseating Aristotle from his position of philosophical dominance and, given the persecution they faced, did not garner many followers, they did leave their contemporaries and successors with an increased awareness of the possibility of developing viable philosophical alternatives to Aristotelianism. Criticism of Aristotle on specific issues for his obscurity and internal inconsistencies became increasingly common.[58] While some tried to develop an entire philosophy based on an ancient authority other than Aristotle, others combined Aristotelianism with positions borrowed from a mix of the different thinkers that had recently been rediscovered.[59] Philosophical diversity also prompted two new kinds of responses: syncretism on the one hand and skepticism on the other.

Giovanni Pico della Mirandola (1463-94) set the standard for the syncretic position, in gathering 900 theses drawn from a wide range of philosophical traditions, from the medieval Arabs to the hermetic texts, with the idea of showing that each philosophical tradition was an incomplete manifestation of a single (Christian) truth. Although this work (the Conclusiones, 1486) was condemned by pope Innocent VIII in 1488, it was widely read and cited in the Renaissance, in part for its doxography (i.e., its collection of philosophical opinions) and in part for its syncretic approach, which was perpetuated by Francesco Giorgi (1460-1540) and Agostino Steuco (1497-1548) among others.[60] By contrast, Giovanni Pico's nephew Gianfrancesco Pico della Mirandola (1469-1533) concluded from the same variety of philosophical opinion that all philosophy is false, and that only the Christian faith offers certainty. The persistent appeal of this skeptical, fideist position in the sixteenth century, to authors ranging from Henricus Cornelius Agrippa von Nettesheim (1486-1535) to Michel de Montaigne (1533-92) and Francisco Sanchez (1550/1-1623),[61] prompted René Descartes (1596-1650), Marin Mersenne (1588-1648), and Francis Bacon (1561-1626), among others in the early seventeenth century, to look for a more solid foundation than philosophical authority on which to ground natural knowledge.

The Impact of the Reformations and of Religious Concerns

A second challenge to received Aristotelianism stemmed from the renewal of moral and religious objections. Francesco Petrarca, or Petrarch (1304-74) was one of the first to mock Aristotelianism as sterile and irrelevant to the real (ethical and religious) concerns of life. Petrarch complained bitterly of those who attacked him because he refused to worship Aristotle as they did and instead pointed out the limitations of philosophical knowledge when compared with the rewards of religious contemplation:

> Thus we come back to what Macrobius says .... "It seems to me that there was nothing this great man [Aristotle] could not know." Just the opposite seems to me true. I would not admit that any man had knowledge of all things through human study. This is why I was torn to pieces, and ... this is what is claimed to be the reason: I do not adore Aristotle. But I have another whom to adore. He does not promise me empty and frivolous conjectures of deceitful things which are of use for nothing and not supported by any foundation. He promises me the knowledge of Himself.[62]

Petrarch raised the classic Christian objections to Aristotle, which had motivated the condemnation of Aristotelianism when it was first introduced in the universities in the thirteenth century.[63]

Although Aristotle had so rapidly and effectively been Christianized (through the work of Thomas Aquinas among others) that by 1325 he had become the standard philosophical authority in universities, religious objections to Aristotle became once again a powerful line of attack against his authority in the Renaissance.[64] In particular Aristotle's discussions of the eternity of the world, the necessity of natural law and the immortality of the soul were not obviously in agreement with Christian doctrines about the creation of the world, the possibility of miraculous exceptions to the laws of nature, and the survival and judgment of the individual soul after death. Throughout the early modern period natural philosophers had to show how Aristotelianism or any other philosophical system they would prefer to it could be reconciled with Christian doctrines on these issues. As a result the eternity of the world and the immortality of the soul were often standard topics in early modern natural philosophy.[65]

At the same time as the humanists leveled these strictures against scholasticism, the Church also became increasingly hostile to the scholastic separation between philosophy and theology that gave philosophers in the faculty of arts a degree of institutional and intellectual independence. Instead, at the Fifth Lateran Council (1512-17), the Church called on philosophy to play an active role in supporting religious doctrines and launched an offensive in particular against the Averroist strand of Aristotelianism represented in many Italian universities. The Council mandated that philosophers demonstrate the immortality of the soul, whereas a number of scholastic philosophers had long since concluded that this question could not be resolved on philosophical grounds alone.

Defending the independence of philosophy from such religious mandates, Pietro Pomponazzi (1462-1525), professor at Padua, flaunted the decree of the Lateran Council in his On the immortality of the soul (1516), in which he concluded that the soul could be shown on purely rational grounds to be mortal rather than immortal. After a papal condemnation in 1518, Pomponazzi published a Defensorium including orthodox proofs of the immortality of the soul and refrained from publishing his other highly naturalistic treatments of fate and miracles.[66] Nonetheless, Paduan Aristotelians continued to be known for their commitment to naturalistic Aristotelianism. Cesare Cremonini (1550-1631), for example, did not attempt to Christianize his interpretation of Aristotle's position on the eternity of the world and denied the intervention of God in the sublunary realm; for this he was investigated by the Inquisition, though he retained his high-paying position at the University of Padua.[67] But Cremonini remained the exception. Over the course of the sixteenth century most Aristotelian natural philosophers conformed to religious tenets or avoided questions with theological implications, leaving them to metaphysics.[68]

More generally, the new awareness of the shortcomings of Aristotle even among Aristotelians led them to think of themselves as increasingly independent philosophers. For example, the German professor of philosophy Bartholomaeus Keckermann (1571-1609) distinguished the “bad Peripatetics,” who were concerned only with what Aristotle said, from the good ones, like himself or the Paduan philosopher Jacopo Zabarella (1533-89), who pursued the truth beyond what Aristotle had established.[69] Indeed Zabarella described his goal as the pursuit of reason rather than Aristotelian authority. In his treatises on logic and method he drew on the full range of sources available in his day, including medieval and the newly recovered ancient commentaries as well as sources outside the Aristotelian tradition.[70] Many late Aristotelians justified taking liberties with their chosen authority by reiterating in various forms a dictum first coined by Aristotle himself to explain his own independent search for truth: "amicus Plato, sed magis amica veritas" ("Plato is my friend, but truth is a greater friend").[71] For example, the general of the Dominican order, Thomas de Vio, known as Cardinal Cajetan (1468-1534), preferred Thomas Aquinas as an authoritative philosopher to the Aristotle whom Aquinas was supposedly interpreting. In response to Pomponazzi's irreligious interpretation of Aristotle, Cajetan concluded that Aristotle had deviated from the true principles of philosophy, notably on the question of the immortality of the soul.[72]

Among Protestants, the desire to be rid of the medieval legacy of scholasticism led to an initial contempt for Aristotle, most notably by Luther. After an early attempt to use lectures on Pliny and natural history as an introduction to natural philosophy, Philip Melanchthon (1497-1560) returned to Aristotelian categories and scholastic methods in devising the Lutheran curriculum.[73] Among

Calvinists, there was some attempt, notably by the French theologian Lambert Daneau (1530-95), to devise a "Christian physics" based primarily on the Bible.[74] But even Daneau strove to reconcile Aristotelian opinion with the Biblical statements.[75] In the main, the Calvinist professors of philosophy at the new German universities composed Aristotelian textbooks where the usual topics were “reduced” according to Ramist principles. Lutheran and Calvinist commentators on Aristotle readily relied on and cited Catholic authorities like Suarez or Zabarella.[76] Although the reverse was less often the case (presumably due to Catholic censorship), this cross-confessional contact is evidence of the fundamental similarities between Catholic and Protestant Aristotelianism.

The Reformations, both Protestant and Catholic, also had an impact on the justifications of natural philosophy, in bringing back to the fore a concern for Christian (and not specifically denominational) piety. Textbooks of all confessions framed natural philosophy as a pious exercise. In what he boasted was the first work of its kind, a Compendium naturalis philosophiae (1542), the Franciscan Frans Titelmans began with a three-page prose “psalm to the Creator, the one and triune Lord” and each of the twelve books into which his 400-page work was divided closed with similar psalms. This intermingling of psalmic piety with a pedagogical exposition of Aristotle would not become a lasting feature of the textbook genre, but it reveals the uneasiness of the author in presenting Aristotle “straight up,” especially to the broad and inexperienced readership targeted by an introductory textbook.

Through the psalms Titelmans meant to give concrete expression to his objectives, which remained the refrain of all natural philosophy textbooks and treatises for well over a century:

> I saw that the discipline of physics, if it was treated rightly and according to its dignity, was of the greatest importance to sacred Theology and for the fuller knowledge of God; and led in an admirable fashion not only to the knowledge of God, but also to excite the love of God: which two things (that is, the knowledge and the love of God) must be the final and principal end of all honorable studies.[77]

Similarly, Protestant textbooks, following the lead of Melanchthon, praised natural philosophy as an incitement to piety for revealing the benevolent providence of God. The actual practice of natural philosophy was not much affected by these reiterations, but they gave renewed prominence to natural theological arguments from design that defended the existence and worship of God against what contemporaries perceived as a threat from the rise of atheism.[78]

Given its general natural theological usefulness, natural philosophy elicited considerable agreement across confessional lines, not only within Christianity, but also among the Jewish minorities concentrated in Italian cities and in central and Eastern Europe.[79] Although Jews were not often included in the natural philosophical discussions among Christians in the early modern period, the late Renaissance (c. 1550-1620) was a period of relative openness of Jewish thinkers to Christian scientific developments.[80] In particular David Gans (1541-1613), who lived in Prague and maintained contacts at the court of Rudolf II, notably with Tycho Brahe (1546-1601) and Johannes Kepler, tried to promote natural philosophy among his Jewish contemporaries in the hope of enhancing relations between Jews and Christians. He saw in natural philosophy a theologically neutral area by the study of which Jews could improve their standing among Christians.[81] Although Gans' works were not published in his day and scientific study remained peripheral in Jewish education, rabbis like Moses Isserles in Cracow and the Maharal (Judah Loew ben Bezalel) in Prague encouraged naturalistic pursuits and recognized natural philosophy as a legitimate sphere of knowledge separate from the sacred. In addition, the number of Jews studying medicine at Padua rose steadily from the sixteenth to the eighteenth centuries, ensuring the diffusion of a secular medical training to Jews who returned to practice medicine in their towns of origin.[82] Nevertheless, the attractiveness of the kabbalah with its very different mode of thought on the one hand and the pressures of the well-established pattern of cultural isolation in which most Jews lived on the other kept in check a wide acceptance of natural philosophy in Jewish circles.[83]

New Scientific Observations and Practices

Aristotelian natural philosophers responded to new scientific observations and practices, in such areas as astronomy, natural history, or magnetism, which originated outside the universities. The development during the Renaissance of new sites of scientific practice, such as observatories, laboratories, princely courts, foreign travel, or technical schools providing instruction in navigation and other mathematical arts generated new approaches to nature quite foreign to the bookish and disputatious methods of Aristotelian natural philosophers.[84] Bypassing the university's once solid monopoly on scientific discourse, in the sixteenth century autodidacts and artisans could, thanks to printing, both learn from and contribute to widely diffused discussions about nature. [See BENNETT] For example, Niccolò Tartaglia (1499/1500-1557), the son of a post-rider, who taught himself mathematics, from the alphabet to the solution to third-degree equations, worked as a teacher of mathematics in Venice; in what was likely a bid for patronage, he dedicated to the duke of Urbino, Francesco Maria della Rovere, a study of ballistics in which he determined the angle at which a cannon should be pointed to maximize its range.[85] Or Bernard Palissy (1510-90), a potter employed by the French Queen Catherine de Medici, articulated his pride in his artisanal knowledge of the interactions of water and clay in a vernacular dialogue in which empirically-minded "pratique" consistently mocked and defeated the learned pretensions of "theorique."[86] Authors in these new modes of natural philosophical inquiry worked independently of and often with hostility to the universities. Nonetheless a few innovations developed outside the universities were selectively incorporated into university teaching.

Certainly one of the great challenges to Aristotelian natural philosophy stemmed from the accumulation of theoretical and observational innovations in astronomy. Copernicanism was discussed but almost universally dismissed in universities prior to 1640; the principal exception was a circle of scholars associated with the University of Wittenberg who were willing to entertain Copernicanism as a useful hypothesis in the 1560s and 1570s.[87] From the early seventeenth century on, however, the theory was gradually given more careful consideration.[88] At Paris and other Catholic institutions, the Tychonic system was generally preferred until the acceptance of Cartesianism (in the 1690s at the University of Paris) or Newtonianism (e.g., in the liberalized climate in Rome in the 1740s). The papal ban on works expounding heliocentrism was finally lifted in 1757.[89] Although immune to the papal condemnation of Galileo (1633), Protestants too raised objections to Copernicus on physical and biblical grounds. For example, Christian Wurstisen (1544-88) was forbidden from teaching Copernicanism at the University of Basel after he had begun to do so while he taught mathematics there from 1564 to 1586.[90]

For Protestants and Catholics alike, to accept heliocentrism required jettisoning many fundamental tenets of Aristotelian physics and opening oneself to considerable religious objections. In particular, Aristotelian physics dictated that the earth, as the heaviest of the elements, naturally rested at the center of the universe, whereas only the celestial bodies made of the perfect fifth element could revolve in eternal circular motion. Biblical passages like Joshua 10:12, in which Joshua asked the sun to "stand still over Gibeon" to give him more time to finish a battle, seemed a powerful objection to many—from Catholics like Cardinal Bellarmine, who saw in Galileo's arguments no grounds for replacing the traditional interpretation of the Church fathers, to Protestants like Tycho Brahe, who felt that such Biblical statements about philosophy should be acknowledged as authoritative and unambiguous.[91]

There were nonetheless innovations in astronomy less radical than heliocentrism itself to which Aristotelian natural philosophy proved more permeable. These included the discovery by Tycho Brahe, from his well-equipped observatory on the Danish island of Hven, that there was no observable parallax for the comet of 1577. Brahe concluded that the comet had appeared in the highest regions of the heavens, above the sphere of the moon. Like the new star of 1572, which he had already described, the comet therefore constituted an example of change in the part of the heavens that was immutable according to Aristotelian cosmology. Reaction among natural philosophers to this specific challenge to Aristotelian theory of the heavens was varied. At the University of Paris, for example, one professor rejected Brahe's parallax measurement (although it certainly was the best available); another discussed comets and the arguments for and against their superlunary nature without concluding one way or the other; another allowed that there were two kinds of comets—some were sublunary, as Aristotle described, and others superlunary, like that observed by Brahe, and of supernatural origin; another still simply abandoned the traditional sub- and super-lunary distinction in favor of a fluid heaven, following Brahe and the Stoics.[92] [see DONAHUE] In these various ways these Aristotelian natural philosophers absorbed the observation into their philosophical scheme without any threat to their Aristotelian allegiance. The same was true of the sunspots and the irregularities of the moon observed through the telescope by Galileo, which also violated the Aristotelian principle of the immutability of the superlunary world.[93] Thus a number of Aristotelian natural philosophers were aware of and willing to accept some recent astronomical innovations.

The Renaissance also witnessed an explosion of natural historical knowledge prompted by voyages to the New World and by an increased documentation of the flora and fauna of regions both exotic and familiar. Although Aristotle himself was a keen observer of natural particulars and composed a number of natural historical works, natural history did not get much attention in the standard cursus of Aristotelian natural philosophy. It was rather the purview of medical doctors, seeking to catalogue remedies in mineral, vegetable, and animal substances. One university professor of philosophy explained in the early seventeenth century that natural history was rarely taught because its topics were not demonstrative nor difficult enough to require a teacher and because there was not enough time to fit them into the philosophy curriculum.[94] Textbooks of natural philosophy generally simply enumerated the large categories of natural history (birds, quadrupeds, fish, snakes, and insects, for example) without paying any attention to the particular features of each species that would detract from the universal quality of the scientia of natural philosophy.[95] Authors working outside the universities, free from the time constraints of a set curriculum and generally more open to a broader range of recent work in natural history or travel accounts, often devoted more attention to natural particulars, as in Girolamo Cardano's De subtilitate rerum (On the subtlety of Things, 1550) and De rerum varietate (On the Variety of Things, 1557) or Jean Bodin's Universae naturae theatrum (Theater of universal Nature, 1596).

Nonetheless, observations from the New World and other places entered Aristotelian natural philosophy at the universities in various ways. [See FINDLEN, "Natural History," and VOGEL, "Cosmography"], For example, all commentators acknowledged that recent experience had disproved the ancient notion that the torrid zone was uninhabitable. The Jesuit commentators at the University of Coimbra in Portugal (active 1592-98), for example, debated in their frequently reprinted commentaries on Aristotle the number of continents, the proportion of sea and land, and adduced a mix of ancient, medieval and modern authors, explicitly noting the priority of experience over received authority on these issues.[96] The Jesuits were also well known for their courses on geography, which integrated the reports of faraway missionaries, and tutored the future ruling elites of different nations in local geography and hydrography—hardly Aristotelian topics.[97] Perhaps in conscious emulation of the Jesuits, perhaps in response to the interests of their students, who were also destined to be officers of the new bureaucracies, university professors could also include natural historical and geographical topics ranging well beyond the prescribed Aristotelian texts. For example, student notes extant in manuscript and published form show how one professor at Paris in the 1620s, Jean-Cecile Frey, discussed the New World in a physics course of 1618 after offering more standard commentaries on On the Heavens and On Generation and Corruption. Professors could also introduce a broad range of topics in extracurricular instruction, which was especially common in the residential colleges of Oxford or Paris. This was the most likely locus for Frey's more unusual courses—on druidic philosophy and the "admirable things of the Gauls" (covering the noteworthy natural and human features of contemporary France) or on "curious propositions about the universe," which contained a motley selection of travel lore.[98]

The Jesuits were particularly noted among Aristotelian natural philosophers for their openness to new empirical and mathematical methods. Although they did not practice experiments or the observation of specific, punctual events, the Jesuits are credited with incorporating the evidence of common experience in theorizing about natural philosophy.[99] The Jesuits harbored magneticians like Niccolò Cabeo (1586-1650) and Athanasius Kircher (1602-80), who adopted the experimentalism of William Gilbert (1544-1603), although the Society formally banned some of Gilbert's propositions in 1651.[100] At the Collegio Romano especially, which trained the elite of the Jesuit intellectuals, professors like Christoph Clavius (1537-1612) kept abreast of new developments in the mathematization of physical phenomena like motion, which seemed an impossible crossing of disciplinary boundaries to most traditional Aristotelians.[101] [See BENNETT, BERTOLONI MELI] Throughout the seventeenth century, the Jesuits included prominent astronomers noted for their observational feats despite their continued allegiance to Aristotle and the Tychonic system.[102]

Even at the universities there was some penetration of the new methods. Starting in the late sixteenth century, universities throughout Europe increasingly featured botanical gardens and anatomy theaters, generally associated with the medical faculties, and (in the seventeenth century) observatories and chemical laboratories.[103] At Oxford and Cambridge, chairs were established in the mathematical disciplines: the Savilian chairs of geometry and astronomy were founded at Oxford in 1619 and 1621 and the Lucasian chair of mathematics at Cambridge in 1663.[104] Students' notebooks and book ownership records provide evidence of both formal and informal instruction in geography at Oxford and Cambridge.[105] Students could also engage in extracurricular scientific activities in the laboratories that friends or tutors kept in their rooms.[106] Although many a new philosopher complained that his years of study were wasted,[107] instruction in early modern universities could be quite wide-ranging and could integrate new elements of theory and practice. Official curricula, like most university statutes or the Jesuit ratio studiorum, generally mentioned only Aristotelian works and in some cases called explicitly for allegiance to them.[108] But official curricula do not give us a full picture of the teaching to which a student was actually exposed. Professorial treatises and student notes and commonplace books, many more of which deserve to be studied, reveal the diversity of topics that students encountered, from the private laboratories in some college rooms in Cambridge to the druids in Frey's extracurricular Paris instruction or the Presocratics praised in the teaching of one Paduan professor in the 1640s.[109] Nonetheless, exposure to new methods and topics remained an optional extra and never took on the dominant or obligatory character of the more traditional parts of the curriculum.

Resistance to Radical Innovation

Given the diversity of opinion it embraced, early modern Aristotelian natural philosophy cannot easily be defined as a set of philosophical positions.[110] One scholar has concluded that, "probably not one of Aristotle's doctrines was held by all early modern scholastics."[111] Certainly most Aristotelian philosophers adhered to a set of core beliefs. The three principles of form, matter, and privation constitute the bedrock of Aristotle's theory of substance and change (called hylemorphism, from hyle, matter and morphe, form). [See JOY] Matter is passive, but has the potential to become a substance when it is informed by a substantial form; form is the active principle that gives qualities to the substance and experiences change. Privation, or the absence of form, is necessary to explain the state of matter before it becomes substance, but its importance to late Aristotelians was on the wane.[112]

Most famously, Aristotelians adhered to the notion that the sublunary world consisted of four elements—air, earth, water, and fire; but late Aristotelians did not hold unanimously even this central tenet. For example, one Théophraste Bouju, royal counselor and almoner, who claimed for his vernacular coverage of quadripartite philosophy in 1614 the authority of Aristotle, nonetheless rejected fire as an element.[113] This was also the position of the Italian physician Girolamo Cardano, who in his mid-sixteenth-century works of philosophy and medicine prided himself on rejecting the received authorities, respectively Aristotle and Galen.[114] The main difference between the two resides not in their actual position rejecting fire as an element but in the way in which they couched it: whereas Bouju proclaimed himself an Aristotelian, Cardano thought of himself and was thought of by contemporaries as an anti-Aristotelian innovator ("novator")—a term freighted, unlike today, with mostly negative connotations. Given the doctrinal flexibility of "Aristotelianism," self-definition was a key factor to consider in distinguishing an eclectic Aristotelian from a critic of Aristotle, since both might share some of the same positions despite being in opposing camps.[115]

Although Aristotelian natural philosophers in the early modern period boasted of novelties of their own and took liberties with received Aristotelian philosophy, they bristled at explicit attacks against Aristotle. From Theophrastus Bombastus von Hohenheim, or Paracelsus (1493-1541), who called for bonfires of authoritative texts at the University of Basel in 1527, to the three young philosophers at the University of Paris who advertised in 1624 a public defense of 14 atomist theses “against Aristotle, Paracelsus, and the Cabbalists,” those who publicly attacked Aristotle were rapidly condemned. Paracelsus was drummed out of Basel and the 1624 disputation, forbidden by the Sorbonne in a ban enforced by the Parlement of Paris, never took place.[116] In both cases the attacks on Aristotle were perceived to threaten the stability of the institutional university hierarchy and by extension of society itself. The three young philosophers provoked such a reaction at a time when in less formal, private venues similar challenges to Aristotle were probably being discussed, because they were perceived not as disinterested seekers after truth, but rather as arrogant troublemakers, intentionally attracting large crowds to hear their scandalous attacks on their elders' orthodox doctrines. University and civil authorities cracked down hard, particularly since the bloody consequences of doctrinal disputes during the recent wars of religion (1562-98) were still vividly remembered.[117]

Explicit anti-Aristotelianism, especially when it threatened to strike within the university, triggered reiterations of the commitment to Aristotle that one finds in official documents.[118] University professors were not the only ones to defend Aristotle when a wave of anti-Aristotelian works appeared in the 1620s. The Minim Marin Mersenne (1588-1648), who maintained a large international network of correspondents and both convened and attended the kinds of informal gatherings that were especially interested in new philosophies, nonetheless judged quite harshly those who wrote against Aristotle:

> [Aristotle] transcends all that is sensible and imaginable, and the others crawl on the earth like little worms: Aristotle is an Eagle in Philosophy, the others are only like chicks who want to fly before having wings.[119]

Late Aristotelian natural philosophers may have become increasingly eclectic in the positions they embraced and thought of themselves more as independent philosophers than as commentators of the Philosopher, but they also became increasingly strident in their explicit allegiance to and defense of Aristotle against detractors. This explicit allegiance was what they had most unambiguously in common.

Despite a certain presence of new empirical and mathematical methods at the universities, Aristotelian natural philosophers could not accept the call to reject received philosophy and ancient authorities as mere opinion and to build certain knowledge instead on mathematical and empirical foundations. Aristotelian natural philosophy was defined as the search for scientia or certain knowledge, to be acquired through deductive causal explanation rather than empirical or mathematical description; the new philosophies of the seventeenth century would share this goal of causal explanation, but proposed very different methods from the bookish cycle of philosophical discussion practiced by the Aristotelians. The philosophies of the sixteenth century, by contrast, which relied on replacing Aristotle with an alternative ancient philosopher as their champion (e.g., Plato, Epicurus, or the Stoics) by and large perpetuated the methods of Aristotelian natural philosophy. These traditional natural philosophies were overwhelmingly bookish in their sources, drawing their explananda from authoritative texts rather than from observations of nature or experiments. Their explanations relied on dialectical argumentation rather than mathematical demonstration; and their motives were entirely speculative, with no concern for the possibility of practical applications. By contrast, the mechanical philosophers, who prevailed by the end of the seventeenth century and called for experiments to acquire data or confirm theory, strove for mathematical laws as the ideal expression of natural phenomena and promised (albeit often on the thinnest of grounds) practical applications for the future. [see DEAR] After successfully weathering the threat of alternative traditional natural philosophies through the mid-seventeenth century, and issuing strident condemnations of the mechanical philosophers as late as the 1670s, Aristotelianism finally succumbed first to mechanical philosophy, and then to Newtonianism.

The mechanical philosophy was flexible enough to embrace both experimentation and mathematization and a radical enough departure from Aristotelianism that attempts to reconcile the two (in philosophies dubbed "nov-antiqua") did not have broad success. Cartesianism first entered the French universities, one of the last major bastions of Aristotelianism, in the 1690s, although near Barcelona students were still producing under dictation courses in the old style, commenting on the Physics and the On the Heavens through the eighteenth century.[120] After 1668 no new Latin editions of the works of Aristotle were issued until the activities of classical scholars in the nineteenth century.[121]

Forces for Change in the Seventeenth Century

While the Aristotelians controlled the universities, the "new philosophers" relied on new kinds of institutions to develop their ideas and gain a following. These more or less formal gatherings ranged from "academies" with princely patronage to informal meetings in individual homes. Often formed on the model of literary societies, the groups that focused on scientific questions operated in the vernacular. The first may well have been the group of curiosi that Giambattista della Porta (1535-1615) gathered around him in Naples in the 1560s as the Accademia dei Secreti; membership was reserved for those who could contribute a new observation. The Roman Accademia dei Lincei, founded by the nobleman Federico Cesi in 1603, famous for including Galileo among its members, and the Florentine Accademia del Cimento, founded in 1657, were both especially oriented toward the collection of observations and the performance of experiments.[122]

In the Holy Roman Empire scientific societies appeared later, starting in the mid-seventeenth century, and focused especially on attempts to form a pansophic philosophy to counteract the religious and political splintering of the Empire as consolidated by the Thirty Years War. The short-lived Societas Ereunetica, the Academia Naturae Curiosorum founded in Schweinfurt in 1652 (reorganized in 1677 as the Academia Leopoldina under the auspices of the Emperor but with no fixed location), and the Collegium Experimentale founded in Altdorf in the 1670s respectively promoted rosicrucianism, alchemy, and the study of mirabilia; these emphases accentuated the growing cultural divergence between Eastern and Western Europe.[123] More successful in gaining a European-wide audience were the Acta eruditorum, a learned journal founded in Leipzig in 1682 and the plan for a "Societas scientiarum" conceived by Gottfried Wilhelm Leibniz (1646-1716) among many other projects for implementing his utopian visions of international scientific and philosophical collaboration. The plan called for a society under the patronage of the elector of Brandenburg comprised of members based in Berlin and correspondents reporting from elsewhere, divided into departments of physics, mathematics, German languages, and literatures. Although the plan was adopted in 1700 with Leibniz as the Society's president, the Berliner Sozietät der

Wissenschaften was inaugurated only in 1711 due to difficulties in securing sufficient revenues.[124] In England and France a series of informal gatherings starting in the 1630s culminated in the foundation of the Royal Society in 1662 and the Académie Royale des Sciences in 1666, which both emphasized the utilitarian goals of science following the ideals of Francis Bacon.[125]

Amid these various gatherings of the early seventeenth century, the multiplication of attacks on Aristotle and the sense that skepticism was a dangerous threat to be countered created an atmosphere in which it seemed that anyone could offer a "new philosophy." For example, the Bureau d'Adresse of Théophraste Renaudot held weekly discussions on philosophy from 1633 to 1642, in which the public was invited to participate according to rules that called for reasoned and amiable interchange on any philosophical topic excluding politics and religion.[126] Judging from the printed record of these sessions (in which the participants remain anonymous), a wide range of questions were debated, in French, around Aristotle and the new philosophies: from traditional questions about the origins of motion, vapors or thunder, or whether one can demonstrate the immortality of the soul, to questions of more recent origin concerning the merits of such novelties as heliocentrism, and the mechanical and chemical philosophies. Richelieu, whose support made the existence of the Bureau possible, may well have initiated discussion of practical questions about navigation and how to determine longitude.[127] At a more select and less formal venue in Paris, a lecture at the home of the papal nuncio in Paris in 1628, where one Sieur de Chandoux was touting his philosophical system, Descartes rose to refute him and impressed Cardinal Bérulle, who then enjoined Descartes to carry on the search for a new philosophy.[128] Descartes' brief from this leading figure of the French Counter-Reformation was to combat skepticism by devising a new philosophy that would be both certain, to counter the skeptics, and pious, to counter the impieties proposed in place of Aristotle.

The Origins of the Mechanical Philosophy

In the 1620s a European-wide spate of anti-Aristotelian works appeared, notably by the Frenchman Sebastian Basso (fl. c. 1560-1621), the French Oratorian Pierre Gassendi (1592-1655), the Dutchman David van Goorl (b. 1591), and the Englishman Nicholas Hill (c. 1570-1610), all of them atomists.[129] Rather than a single philosophy, atomism designates loosely a number of different theories premised on the idea that matter is constituted of the coalescence of indivisible atoms.[130] Some atomists, like Daniel Sennert (1572-1637) professor at the University of Wittenberg, were keen to derive the notion from Aristotle and to do so relied on passages in Averroes' commentary which discussed the existence of smallest units of a substance or "minima naturalia";[131] this was the kind of atomism most often found in university contexts.[132] Others couched their theories as refutations of Aristotelian physics, grounded in an alchemical notion of “seeds” of matter (Paracelsus, Michael Sendivogius, and Johannes Baptista van Helmont) or in Epicureanism.[133]

Gassendi proposed a full-scale revival of Epicureanism, an ancient philosophy long reviled as irreligious because of its explanations based on the chance encounters of atoms. To make Epicureanism compatible with Christianity (and even more “pious” than Aristotelianism, he claimed), Gassendi rejected the Epicurean notion of eternal uncreated atoms. Instead, Gassendi maintained that atoms were divinely created and endowed with motion by God, and he introduced into the strictly naturalistic system of Epicurus immaterial beings, including angels and rational souls, which did not jeopardize the atomic structure of material ones.[134] Gassendi directed his system against the Aristotelians, but by mid-century it became clear that the main opposition to Aristotelianism would come from another innovator, René Descartes (1596-1650). Whereas Gassendi’s works were never translated from Latin, Descartes’ theories were more broadly popularized, notably in French.[135] Furthermore Descartes’ followers proved skilled at adapting his original philosophy in response to objections, easing its spread into the universities.[136]

Descartes’ philosophy can be seen as a kind of atomism, although Descartes differed from Gassendi on infinite divisibility, which Gassendi denied, and on the existence of the void, which Descartes denied. In the Discours de la méthode (Discourse on method) of 1637, Descartes described how through systematic doubt he eliminated all previous philosophical commitments as mere opinion and started from scratch to build a solid philosophy based only on "clear and distinct" ideas.[137] From the existence of the thinking self (cogito ergo sum) Descartes established the existence of God, guarantor of the truth of the clear and distinct ideas, and, by further rational deduction, the building blocks of an entire cosmology. From the basic principles that matter is extension, that all phenomena can be explained as matter in motion, and that secondary qualities can be reduced to the primary qualities of size, shape, and motion, Descartes envisioned the world as a plenum of particles of matter of various sizes set in motion by God and self-perpetuating since then. The interaction of the particles according to various rules of impact had generated all natural phenomena—from the planets and their movement in circular vortices to the sensations of taste or smell in the body. Descartes' philosophy was designed as a complete overhaul of existing philosophies, Aristotelian and atomist. Because of his commitment to heliocentrism, he feared that his work would be placed on the index following the condemnation of Galileo in 1633, and as a result he left his cosmological treatise Le monde (The world) unpublished during his lifetime.

It is not easy to explain the success of Cartesianism.[138] Like other new theories, it caught the fancy of the young especially, among whom it generated unusual enthusiasm. Christiaan Huygens (1629-95), for example, described with some bemusement in later years how he was enthralled, at the age of 15 or 16, by the novel and pleasing aspect of the vortices of particles that constituted Descartes' cosmology.[139] The enthusiastic support of the younger and more reckless of contemporary philosophers certainly did not enhance the appeal of Cartesianism to the rest of the philosophical community. At the recently founded University of Utrecht, the bold teachings of Henricus Regius (1589-1679), which were never condoned by Descartes, prompted an official condemnation of Cartesianism in 1641.[140] Professors at Utrecht were forbidden from teaching Cartesianism on the grounds that it undermined the foundations of traditional philosophy and the acquisition of the technical terms commonly used by traditional authors, and because "various false and absurd opinions either follow from the new philosophy or can rashly be deduced by the young."[141] Although Cartesianism was banned in Leiden, too, the Low Countries also harbored some of the earliest university interest in Descartes, notably at the new institution of Groningen.[142]

In France Cartesianism was condemned by the king and the university (in 1671) after Cartesian attempts to account for the Eucharistic transformation had been condemned by the pope in 1663.[143] But outside the universities Cartesianism inspired the friendly critique of the Jansenist Antoine Arnauld (1612-94), which marked the beginning of the association many contemporaries saw between Cartesianism and Jansenism, an oppositional religious and political faction.[144] Descartes also inspired the occasionalism of the Oratorian Nicolas Malebranche (1638-1715), and, most effectively, the popularization efforts of Jacques Rohault

(1618-72). Rohault gave weekly public lectures in Paris expounding Descartes' physics, which even included experiments. His Traité de physique (1671) became the standard textbook of Cartesian physics and was used, in Latin then English translation, across the Continent as well as at Oxford and Cambridge.[145] Rohault's success, like that of Robert Chouet, who introduced Cartesian physics at the Academy of Geneva in 1669 without provoking controversy, rested on the strategy of minimizing the differences between Cartesianism and Aristotelian natural philosophy.[146]

The eclecticism of Cartesians willing to compromise on the points that most irked Aristotelians (among them Descartes' rejection of hylemorphism, his heliocentric cosmology and his mechanistic interpretation of animals) certainly contributed to their success. For examples, Cartesians lecturing at the university were often willing to put their views in an Aristotelian framework, by organizing their discussions under such scholastic headings as "matter" and "form"; some even tried to read Cartesian views into Aristotle, claiming that earlier commentators had misunderstood him.[147] They also avoided claiming heliocentrism as an unimpeachable fact and proposed it merely as a hypothesis; dropping Descartes' metaphysical underpinnings of his physics, they limited Descartes' physics of matter in motion to the inorganic world, thereby skirting the delicate question of sentient beings.[148] Furthermore, a strong institutional separation between philosophy and theology, such as existed in Geneva, enabled Cartesian physics to be adopted without provoking fears of irreligious consequences. In Germany, where there was little tradition of a separation of philosophy and theology, Cartesianism was slow to spread, despite the inroads made by Johann Clauberg (1622-65) in Duisburg.[149] In Italy, Cartesianism appeared as part of a "mechanist syncretism" starting in Naples in the 1660s.[150]

Although Colbert rejected Cartesians as members in the early Académie Royale des Sciences on the grounds that they were excessively dogmatic, after his death in 1683 the Académie became more closely associated with Cartesianism, even more so after Malebranche and Bernard le Bovier de Fontenelle (1657-1757) became members in 1699 (and the latter, secretary of the Académie). The University of Paris followed suit, and Cartesianism became the norm there in the 1690s. The Jesuits, forbidden from teaching the new philosophy, soon found themselves a laughing stock and their classes deserted in the early eighteenth century.[151] Ironically, Aristotelianism yielded to Cartesianism in France just at the time that Descartes' cosmology had been debunked by the work of Huygens and Newton; but the French natural philosophers, loath to abandon their national champion, only cast off Descartes for Newton some fifty years later, in the 1740s.[152]

The Transformation of Natural Philosophy by Empirical and Mathematical Methods

In England the spread of the mechanical philosophy was enhanced by contact with the philosophies of Gassendi and Descartes, not only through print, but also through the travel to France of émigrés during the civil war of the 1640s. Thomas Hobbes and William Cavendish, for example, returned to England enthusiastic about mechanical philosophy.[153] Although Hobbes (1588-1679) favored the rationalist methods of Descartes, most English mechanical philosophers grafted onto the basic principles of matter-in-motion, practices of observation and experimentation inspired by Francis Bacon.[154] Bacon developed no philosophical system to replace Aristotle's and was never successful in his lifetime in gaining the support he sought for a reform of society through a reform of natural philosophy.[155] Nonetheless after his death in 1626 (fittingly, so the contemporary story went, from pneumonia contracted while observing a chicken frozen in winter[156]), his work inspired natural philosophers, especially in England but also on the continent, well into the eighteenth century. Bacon called for a collaborative pursuit of natural knowledge through the systematic observation of nature, both in its natural state and "on the rack," that is, in artificial experiments contrived to highlight otherwise hidden features. In his Novum Organum (New Organon, 1620) designed to replace the logical Organon of Aristotle, Bacon described a method for the careful derivation of generalizations from the accumulation of natural historical particulars.[157]

English mechanical philosophers like Robert Boyle (1627-91) and Robert Hooke (1635-1703) adhered to the principle that everything could be explained by matter in motion. But they shunned what they perceived to be the dogmatism of

Descartes, with his a priori rationalist assumptions, for example his denial of the possibility of a void. Instead they favored a new experimental method, which differed from the concept of "experience" current among both eclectic Aristotelians and the new philosophers of the Continent (including Galileo, Descartes, and Blaise Pascal [1623-62]). Rather than invoking "experience" unproblematically as what was commonly known to happen in nature and using it as a quick justification to arrive at general principles, the English experimentalists described with precision specific events that actually happened in nature, produced by experimental conditions designed to elicit unusual phenomena (such as the air pump), and they were cautious about offering causal explanations of the observed phenomena.[158] Rejecting explanations that attributed moral qualities to nature (like the "fear of the void" associated with Aristotle), Boyle introduced qualities that he attributed to the particles of matter, such as the springiness of air particles (later interpreted as the discovery of "Boyle's law"), although he could not explain springiness itself in terms of the shape and size of the particles.[159] Boyle remained mindful of the limits of human ability to understand all the reasons of nature and was satisfied, like most English experimentalists, with what he considered to be probable rather than certain knowledge resulting from the experimental investigations.[160]

In a parallel, more mathematical tradition, continental natural philosophers like Galileo and his followers pursued mathematics as the key to certainty in natural philosophy. Although Galileo probably did perform inclined plane experiments, he often idealized “experience” as what would happen in nature under perfect conditions (e.g., in free fall without air resistance).[161] The new physics of motion expressed in mathematical laws that he developed inspired the modifications by Christian Huygens and was a prerequisite to Newton’s synthesis of the new physics with the new astronomy.[162] It also marked the end of the traditional distinction between physics as the science of real bodies and mathematics as the study of abstract and unreal entities. This separation had already been eroded in some circles by the study of “mixed mathematical” disciplines such as optics or astronomy, but it appealed especially to natural philosophers who felt that their discipline was superior to mathematics. In a separate strand of mathematization, Kepler had discovered three laws of mathematical correlations in the planetary motions; his method was grounded in the conviction that God had created the universe according to “number, weight and measure” and therefore according to mathematical laws, and in the painstaking attention to empirical precision with which he manipulated the data collected by Tycho Brahe.[163]

Both Galileo and Kepler carried out much of their innovative mathematical and observational work under the auspices of princely patronage. They began their careers teaching mathematics at the university or equivalent institutions, Galileo first at Pisa then at Padua from 1592 to 1610 and Kepler at the Protestant seminary in Graz from 1594 to 1600. In 1600 Kepler began as Tycho Brahe’s assistant at the court of the Holy Roman Emperor Rudolf II in Prague and became Imperial

Mathematician upon Tycho's death in 1601.[164] In 1610 Galileo was named court mathematician to Cosimo II de Medici, Grand Duke of Tuscany in Florence.[165] In moving to positions at court they were freed from the constraints of often low-paid teaching and of the traditional notions of what should be taught. Both worked to support heliocentrism at a time when Copernicus' theory was considered by others as at best a useful computational tool; they challenged the traditional distinctions and hierarchy between the disciplines in using mathematics to address physical questions about the nature of motion or the cosmos.[166] Similarly, those who contributed most to the development of mechanical philosophy relied mostly on new institutions such as the Royal Society. Though he settled in Oxford in 1656, Robert Boyle was an independently wealthy gentleman with no connection to the University. Isaac Newton held the Lucasian professorship of mathematics from 1669 to 1701, but even before he left Cambridge in 1696 for an appointment as warden of the Mint in London, his teaching elicited almost no notice from students or contemporaries.[167] Instead, Newton sent his first major piece of work, the reflecting telescope, to the Royal Society in 1671; he was elected a fellow in 1672 and then President of the Royal Society in 1703. Despite contentious relations with various fellows, most notably the curator of experiments Robert Hooke (1635-1703), the Royal Society constituted his primary scientific audience.

Newton puzzled many contemporaries by offering mathematical laws but no causal explanations in his Principia mathematica philosophiae naturalis

(Mathematical Principles of Natural Philosophy, 1687); he counted on the certainty of mathematics to forestall the disputatiousness that he so disliked among natural philosophers. But this strategy nonetheless embroiled him in controversy: Leibniz, among others, accused him of reintroducing "occult qualities," [See COPENHAVER] because, although his theory of gravitation provided a single powerful explanation for the tides, the motions of the moon and the planets as well as projectile motion, Newton gave no causal account for gravitation itself, concluding, in his "General scholium":

> I frame no hypothesis; for whatever is not deduced from the phenomena is to be called an hypothesis; and hypotheses, whether metaphysical or physical, whether of occult qualities or mechanical, have no place in experimental philosophy.[168]

Newton moderated this stance somewhat in editions of his Opticks after the addition in 1706 of queries 25-31 containing speculations about the nature of light and of attraction, among other topics.

In addition to his publications on mathematical and physical subjects Newton remained concerned with a full range of traditional topics, as is evident from his abundant theological and alchemical writings left in manuscript.[169] Although he definitively transformed physics into its modern form as a technical mathematical discipline, Newton has been described as the last of the Renaissance natural philosophers. His diverse interests were all part of a quest to understand the workings of God in the world—for example, in nature through the motions of the planets that God regulates and sustains, and in history through the fulfillment of biblical prophecies.[170] One of the ways in which early modern natural philosophy differs from the various "sciences" that later replaced it is that natural philosophy was unified by its search for a better understanding of God—of divine creation (in natural historical disciplines) and divine laws (in the mathematized disciplines).[171]

The Social Conventions of the New Natural Philosophy

By the late seventeenth century the Royal Society of London and the Paris Académie Royale des Sciences played leading roles in defining the practices of natural philosophy that were increasingly imitated throughout Europe and in reforming the universities. The Baconian ideal influenced both institutions, as they pursued in different ways a collaborative model of natural philosophy with utilitarian ambitions.[172] For lack of the royal patronage it had hoped for, the Royal Society was financed by its members, who paid an annual subscription and actively recruited the eminent to enhance its standing. Far-flung members who never attended meetings could contribute observations by correspondence, but the day-to-day activities of the Society were dominated by a core group of less than twenty fellows.[173] The Académie Royale des Sciences was more tightly hierarchized (into honoraires, pensionnaires, associés, and élèves) and at its core comprised an élite of twenty-two members selected first by Colbert, later by the members in session; they received an annual stipend as officers of the king and performed various specific tasks, such as the administration of patents and prizes.[174] Despite these different formats, both institutions hoped to mobilize natural philosophers to undertake collective natural histories, to promote the material welfare of society.

The Académie was assigned by Colbert the task of drawing up an inventory of machines in the country and although they collected models of machines and volumes of careful illustrations, the project was never completed. It then undertook a vast history of plants, instigated by Claude Perrault (1613-88) and directed by various members in turn; but, although some results were published, the project was never realized according to the initial ambitions due to lack of funding and personal rivalries as well as intellectual disagreements, notably concerning the appropriate balance between description and illustration on the one hand and causal explanation and chemical analysis on the other.[175] The sessions were closed, but the proceedings were published in the Mémoires. At the Royal Society an active core of members attended and discussed the results of experiments performed by the curator of instruments. Without a specific agenda, the collaborative accumulation of results was realized in the wide range of material covered in the Philosophical Transactions; these developed a distinctive rhetoric to describe experiments to the members who could not attend and enlist their support as "virtual witnesses" to the phenomena.[176] The model of the natural philosopher as a gentleman, as epitomized for example by Robert Boyle, emphasized civility of conversation over passionate debate as the ideal form of interaction and encouraged members of the Royal Society to present their findings as modest observations of fact with only cautious references to theoretical claims.[177]

Both groups explicitly banned religious and political discussions and dogmatism of any kind (Jesuits and Cartesians were both banned from the Académie by Colbert for that reason). The Royal Society and the Académie Royale des Sciences conferred on natural philosophy a new institutional and intellectual autonomy. In these settings the review and agreement of respected peers constituted the criterion of acceptability instead of adherence to pre-established conclusions set by church or state.[178] Furthermore, the disputatiousness for which traditional natural philosophy had become notorious was considered a vice best avoided in the new environment of the academies. Although results fell short of expectations and perhaps the first functionally useful item to stem from the Baconian research program was Benjamin Franklin's lightning rod (1750), both the Royal Society and the Académie Royale des Sciences successfully propagated the idea that science could be useful to state and society.[179]

Conclusion

The evolution of natural philosophy between 1500 and 1700 can be traced in a nutshell in encyclopedic reference works. Gregor Reisch's Margarita philosophica (1503), two short books on the principles and on the origins of natural things, summarized Aristotle's Physics and sketched his Meteorology and natural histories (with additional material drawn from Pliny). Natural philosophy appeared as a largely static field covered by ancient authorities. A century later the Encyclopedia (1630) of Johann Heinrich Alsted (1588-1638) crystallized many of the developments of the Renaissance. The eight parts in which physics was divided featured Aristotelian notions (principles, elements, meteorological theories), enhanced with new, often modern, even anti-Aristotelian, authorities. Alsted coined new terms and lent credence to new subfields—among them most were traditional topics (mictologia, phythologia, empsychologia, therologia[180]) but they also included "physiognomia," which incorporated Paracelsian signatures and Neoplatonic correspondences. Each part concluded with a peroration vaunting the contribution of that field to piety and the greater glory of God. Aristotle still set the framework for physics, but new authorities, a new conception of independent philosophizing, and a renewed concern for religious piety motivated a work of synthesis that was so eclectic and inclusive as to verge on incoherence.[181] If Aristotelianism had always been a loose baggy monster, this was the monster at its loosest and baggiest.

Less than a century after Alsted, John Harris' Lexicon technicum (1708-10) still used the same terms and elements of definition: “Physicks or natural philosophy is the speculative knowledge of all natural bodies ... and of their proper natures, constitutions, powers and operations.” But the means of achieving the understanding of nature bore no relation to Aristotle’s physics. Instead electricity, effluvia, elasticity, magnetism, and light were the recurring themes; the authorities cited centered around Newton, Edmund Halley, Nehemiah Grew, and Boyle. Traditional philosophies had not disappeared completely from memory, but were assigned a place in a historical/hierarchical classification that made clear the superiority of the new mechanical natural philosophy. First came the Pythagoreans and Platonists, who relied on symbols; next the Peripatetics with their tool box of principles, qualities, and attractions, whose “physicks is a kind of metaphysics.” The experimental philosophers, dominated by the chemists, made many discoveries, but fell into theories and hypotheses. The last were “the mechanical philosophers who explicate all the phenomena of nature by matter and motion ... by effluvia and subtle particles etc ... by the known and established laws of motion and mechanicks: And these are, in conjunction with the [experimental philosophers] the only true philosophers.”[182] Natural philosophy remained a largely speculative search for a causal understanding of the regularities of nature, as Aristotle had defined it, but the forces for change, which accelerated the transformation of Aristotelianism during the Renaissance, unleashed in the seventeenth century a radical restructuring of the discipline around new premises, new practices, and new institutions.

Notes

· I am grateful for helpful comments on earlier drafts of this piece to Roger Ariew, Laurence Brockliss, Mordechai Feingold, Anthony Grafton, and to the editors of this volume.

1. See Robert Boyle, Some Considerations Concerning the Usefulnesse of Experimental Natural Philosophy (Oxford: Printed by Henry Hall for Richard Davis, 1664).

2. The basic principles and strategies of Aristotelian natural philosophy have also survived in restricted, confessional circles down to the twentieth century. See for example Charles Frank, S.J., Philosophia naturalis (Freiburg i.B.: Herder, 1949).

3. For one account of the demise of natural philosophy as a concept after 1800, see Simon Schaffer, "Scientific Discoveries and the End of Natural Philosophy," Social Studies of Science, 16 (1986), 387-420; on the emergence of new terms, see Sydney Ross, "Scientist: The Story of a Word," Annals of Science, 18 (1962), 65-85. In different languages, "natural philosophy" had different connotations. In French "philosophie naturelle" was not as widely used as the English equivalent—"physique" was preferred by both traditionalists like Scipion Dupleix and innovators like the Cartesians. When used in titles, "philosophie naturelle" tended to signal books with hermetic or alchemical interests, as in Jean d'Espagnet's Philosophie

naturelle restituée (Latin 1623; French translation 1651), or Pierre Arnaud, comp., Trois traitez de philosophie naturelle ... ascavoir le secret livre du tres ancien philosophe Artephius (1612) or the anonymous Flambeau de la philosophie naturelle. In German, where Latin persisted longer as the language of science, "Naturphilosophie" first appeared in book titles at the end of the eighteenth century and blossomed with the philosophies of Schelling, Goethe, and others who looked for unifying organic forces in nature.

4. "Physiologia," literally the explanation (logos) of nature (physis), is another near synonym of these terms; for some examples and discussion, see Roger Ariew and Alan Gabbey, "The Scholastic Background," in The Cambridge History of Seventeenth-Century Philosophy, ed. Daniel Garber and Michael Ayers, 2 vols. (Cambridge: Cambridge University Press, 1998), 1: 425-53, esp. pp. 427-8.

5. See Aristotle, Metaphysics, 6.1.1026a. Speculative philosophy was contrasted with practical philosophy, which embraced ethics and the mechanical arts.

6. Chartularium universitatis Parisiensis, vol. 1, no. 246, as cited and discussed in Pearl Kibre and Nancy Siraisi, "The Institutional Setting: The Universities," in Science in the Middle Ages, ed. David Lindberg (Chicago: University of Chicago Press, 1978), p. 131. On the medieval universities more generally, see Universities in the Middle Ages, ed. Hilde de Ridder-Symoens (Cambridge: Cambridge University Press, 1992).

7. For the strand of natural philosophy focused on the soul and what came to be called "psychologia" in the late sixteenth century (which I will not discuss much), see the chapters by Katharine Park and Eckhard Kessler in the Cambridge History of Renaissance Philosophy, ed. Charles B. Schmitt et al. (Cambridge: Cambridge University Press, 1988), pp. 453-534.

8. Edward Grant, Planets, Stars, and Orbs: the Medieval Cosmos 1200-1687 (Cambridge: Cambridge University Press, 1994), p. 20.

9. Maria Rosa di Simone, "Admission," in A History of the University in Europe, vol. 2: Universities in Early Modern Europe (1500-1800), ed. Hilde de Ridder-Symoens (Cambridge: Cambridge University Press, 1996), pp. 285-325, esp. p. 299.

10. Willem Frijhoff, "Patterns," in Universities in Early Modern Europe, pp. 43-110, esp. p. 71. On German foundations, see Beiträge zu Problemen deutscher Universitätsgründungen der frühen Neuzeit, ed. Peter Baumgart and Notker Hammerstein (Nendeln/ Liechtenstein: KTO Press, 1978).

11. Laurence Brockliss, French Higher Education in the Seventeenth and Eighteenth Centuries (Oxford: Clarendon Press, 1987), pp. 19-26.

12. Hilde de Ridder-Symoens, "Mobility" in Universities in Early Modern Europe, pp. 416-48, at p. 432. On Pluvinel see Ellery Schalk, From Valor to Pedigree: Ideas of Nobility in France in the Sixteenth and Seventeenth Centuries (Princeton, N.J.: Princeton University Press, 1986), chap. 8.

13. Richard Tuck discusses the different forms of this trend in different universities in "The Institutional Setting," in The Cambridge History of Seventeenth-Century Philosophy, pp. 9-32, esp. pp. 16-17.

14. For a more detailed account of the different genres of Aristotelica in the Renaissance, see Charles B. Schmitt, Aristotle and the Renaissance (Cambridge, Mass.: Harvard University Press, 1993), chap. 2.

15. I follow Grant's definition of a scholastic as one who was trained at a European university and probably also taught at one for some time, and commented on the natural books of Aristotle. I follow Grant too on the related broad definition of an Aristotelian as one who commented on Aristotle and whose commentary was not solely designed to refute him. Grant, Planets, Stars, and Orbs, pp. 21-3. One can distinguish, as I try to here at various points, between medieval and early modern scholasticism; I reserve "neoscholastic" to describe nineteenth- and twentieth-century movements of Thomist revival.

16. Jill Kraye, "The Philosophy of the Italian Renaissance," in The Renaissance and Seventeenth-Century Rationalism, ed. G. H. R. Parkinson (Routledge History of Philosophy, 4) (London and New York: Routledge, 1993), pp. 16-69, at pp. 24-5.

17. Charles Schmitt, "The Rise of the Philosophical Textbook," in The Cambridge History of Renaissance Philosophy, pp. 792-804, esp. pp. 796 ff. For a survey and bibliography of the genre, see Mary Richards Reif, Natural Philosophy in Some

Early Seventeenth-Century Scholastic Textbooks, Ph.D. dissertation, Saint Louis University, 1962.

18. For examples of this format see Domingo de Soto, Super octo libros physicorum Aristotelis (Venice: Franciscus Zilettus, 1582) or Franciscus Piccolomini, Librorum ad scientiam de natura attinentium partes quinque (Frankfurt: Wecheli haeredes, 1597).

19. Philip Melanchthon, Doctrinae physicae elementa (Lyon: Jean de Tournes and Gul. Gazeius, 1552). On this use of "loci" to structure his textbooks, see Sachiko Kusukawa, The Transformation of Natural Philosophy: The Case of Philip Melanchthon (Cambridge: Cambridge University Press, 1995), p. 174.

20. Guilelmus Adolphus Scribonius, Physica et sphaerica doctrina, 4th ed., with annotations by the English doctor Thomas Bright (Frankfurt: Palthenius, 1600), pp. 188-9. Scribonius taught at the school of Corbach from 1576 to 1583; see Joseph Freedman, "Aristotle and the Content of Philosophy Instruction at the Central European Schools and Universities during the Reformation Era (1500-1650)," Proceedings of the American Philosophical Society, 137 (1993), 213-53. On the diffusion of Ramism, see Joseph Freedman, "The Diffusion of the Writings of Petrus Ramus in Central Europe, c. 1570-1630," Renaissance Quarterly, 46 (1993), 98-152.

21. The first textbook of Aristotelian natural philosophy in French was dedicated to a woman, Jacquete de Mombrom, lady of a number of viscounties and baronies; see

Jean de Champaignac, Physique françoise (Bordeaux: S. Millanges, 1595). Champaignac's work was soon followed by others in the early seventeenth century, including those of Scipion Dupleix (1603), Théophraste Bouju (1614), and René de Ceriziers (1643); see Ann Blair, "La persistance du latin comme langue de science à la fin de la Renaissance," in Sciences et langues en Europe, ed. Roger Chartier and Pietro Corsi (Paris: Ecole des Hautes Etudes en Sciences Sociales, 1996), pp. 21-42, at p. 40.

22. François de Fougerolles, Le Théâtre de la nature universelle (Lyon: Pillehotte, 1597), sig. ++3^r, ++1^v, as discussed in Ann Blair, The Theater of Nature: Jean Bodin and Renaissance Science (Princeton N.J.: Princeton University Press, 1997), pp. 205-6.

23. See Ann Blair, "Authorship in the Popular 'Problemata Aristotelis,'" Early Science and Medicine, 4 (1999), 1-39 and "The Problemata as a Natural Philosophical Genre," in Natural Particulars: Nature and the Disciplines in Early Modern Europe, ed. Anthony Grafton and Nancy Siraisi (Cambridge, Mass.: MIT Press, 1999), pp. 171-204.

24. Schmitt, Aristotle and the Renaissance, p. 54.

25. See Edward Grant, "Medieval Departures from Aristotelian Natural Philosophy," in Studies in Medieval Natural Philosophy, ed. Stefano Caroti (Florence: Olschki, 1989), pp. 237-56, at p. 255.

26. For a study of the range of Renaissance commentary on Avicenna, see Nancy Siraisi, Avicenna in Renaissance Italy: The Canon and Medical Teaching in Italian Universities after 1500 (Princeton, N.J.: Princeton University Press, 1987), p. 177. Biblical commentary could also serve as the opportunity to discuss natural philosophical issues, as in Francisco Vallès, De iis quae scripta sunt physice in libris sacris, sive de sacra philosophia (Turin, 1587). On the genre of the commentary more generally, see Jean Céard, "Les transformations du genre du commentaire," in L'automne de la Renaissance, 1580-1630, ed. Jean Lafond and André Stegmann (Paris: Vrin, 1981), pp. 101-16.

27. François de Dainville, La géographie des humanistes (Paris: Beauchesne, 1940), pp. 222-3.

28. Edward Grant, "Aristotelianism and the Longevity of the Medieval World View," History of Science, 16 (1978), 93-106. The examples of quaestiones are taken from Albert of Saxony (c. 1316-90), "Questions on the eight books of Aristotle's Physics," trans. Edward Grant, in A Source Book in Medieval Science, ed. Edward Grant (Cambridge, Mass.: Harvard University Press, 1974), pp. 199-203, at p. 201.

29. Charles Lohr, "Renaissance Latin Aristotle Commentaries: Authors A-B," Studies in the Renaissance, 21 (1974), 228-89, at p. 228.

30. This estimate is based on a cursory tally of authors contributing to each area in

Charles Lohr, "Renaissance Latin Aristotle Commentaries: Authors A-B," and its sequels in Renaissance Quarterly, 28 (1975), 689-741 ("C"); 29 (1976), 714-45 ("D-F"); 30 (1977), 681-741 ("G-K"); 31 (1978), 532-603 ("L-M"); 32 (1979), 529-80 ("N-Ph"); 33 (1980), 623-734 ("Pi-Sm"); and 35 (1982), 164-256 ("So-Z").

31. Charles Schmitt estimates that 3,000-4,000 editions of Aristotelica appeared in print before 1600, in contrast to approximately 500 editions of Platonica. Schmitt, Aristotle and the Renaissance, p. 14. For a recent bibliography of Platonica, see James Hankins, Plato in the Renaissance, 2 vols. (Leiden: Brill, 1990), 2: 669-796.

32. Eckhard Kessler, "The Transformation of Aristotelianism," in New Perspectives on Renaissance Thought: Essays in the History of Science, Education, and Philosophy, ed. John Henry and Sarah Hutton (London: Duckworth, 1990), pp. 137-47, at p. 146.

33. Schmitt, Aristotle and the Renaissance, p. 92.

34. See John Murdoch, "From the Medieval to the Renaissance Aristotle," New Perspectives on Renaissance Thought, pp. 163-76, at p. 167.

35. Christia Mercer, "The Vitality and Importance of Early Modern Aristotelianism," in The Rise of Modern Philosophy: The Tension between the New and Traditional Philosophies from Machiavelli to Leibniz, ed. Tom Sorell (Oxford: Clarendon Press, 1993), pp. 33-67, at pp. 45-6.

36. This paragraph is indebted to Jill Kraye, "The Philosophy of the Italian

Renaissance," pp. 26-37. See, more generally, James Hankins, Plato in the Renaissance.

37. Notably Theodore Gaza (1400-76) and Cardinal Bessarion (1403-72).

38. James Hankins, "Marsilio Ficino as a Critic of Scholasticism," Vivens Homo, 5 (1994), pp. 325-34.

39. See Brian Copenhaver, Symphorien Champier and the Reception of the Occultist Tradition in Renaissance France (The Hague: Mouton, 1978). There is no synthetic work on the reception of Plato in the seventeenth century; but see Christia Mercer, "Humanist Platonism in 17th century Germany," in Humanism and Early Modern Philosophy, ed. Jill Kraye and M. W. F. Stone (London: Routledge, 2000), pp. 238-58. Note also Mercer's critique of the term "Neoplatonist," pp. 251-2. On Henry More's natural philosophy see Alan Gabbey, "Philosophia Cartesiana Triumphata: Henry More (1646-71)," in Problems of Cartesianism, ed. Thomas Lennon et al. (Kingston: McGill-Queen's University Press, 1982), pp. 171-249.

40. Kraye, "The Philosophy of the Italian Renaissance," p. 47.

41. See in particular Frances Yates, Giordano Bruno and the Hermetic Tradition (Chicago: University of Chicago Press, 1964).

42. This point is made forcefully in Robert Westman, "Magical Reform and Astronomical Reform: The Yates Thesis Reconsidered," in Robert Westman and J. E. McGuire, Hermeticism and the Scientific Revolution (Los Angeles: The William

Andrews Clark Memorial Library, 1977), pp. 3-91. On the difficulties of defining "hermeticism," see Westman, p. 70 and more generally Brian Copenhaver, "Natural Magic, Hermetism, and Occultism in Early Modern Science," in Reappraisals of the Scientific Revolution, ed. David Lindberg and Robert Westman (Cambridge: Cambridge University Press, 1990), pp. 261-302.

43. See Westman, "Magical Reform," p. 30.

44. See Judith V. Field, Kepler's Geometrical Cosmology (Chicago: University of Chicago Press, 1988); and Bruce Stephenson, The Music of the Heavens: Kepler's Harmonic Astronomy (Princeton, N.J.: Princeton University Press, 1994). Recent work has also emphasized the religious origins of his ideas; see Job Kozhamthadam, The Discovery of Kepler's Laws. The Interaction of Science, Philosophy and Religion (Notre Dame, Ind.: University of Notre Dame Press, 1994) and, on a university context devoid of Platonism, Charlotte Methuen, Kepler's Tübingen: Stimulus to a Theological Mathematics (Aldershot: Ashgate, 1998), p. 222.

45. For a recent assessment see James Hankins, "Galileo, Ficino, and Renaissance Platonism," in Humanism and Early Modern Philosophy, ed. Kraye and Stone, pp. 209-37.

46. Notably Giuseppe Biancani (1566-1624) and Jacopo Mazzoni (1548-98); see Paolo Galluzzi, "Il 'Platonismo' del tardo cinquecento e la filosofia di Galileo," in Ricerche sulla cultura dell'Italia moderna, ed. Paola Zambelli (Bari: Laterza, 1973),

pp. 39-79.

47. James Hankins, "Platonism, Renaissance," in Routledge Encyclopedia of Philosophy, ed. Edward Craig, 10 vols. (London: Routledge, 1998), 7: 439-47, at p. 446.

48. See Charles L. Stinger, Humanism and the Church Fathers. Ambrogio Traversari (1386-1439) and Christian Antiquity in the Italian Renaissance (Albany: State University of New York Press, 1977), p. 79; see also Ambrogio Traversari nel VI centenario della nascita, ed. Gian Carlo Garfagnini (Florence: Olschki, 1988).

49. Peter Barker, "Stoic Contributions to Early Modern Science," in Atoms, Pneuma, and Tranquility: Epicurean and Stoic Themes in European Thought, ed. Margaret Osler (Cambridge: Cambridge University Press, 1991), pp. 135-54.

50. On each of these authors, see Alfonso Ingegno, "The New Philosophy of Nature," in The Cambridge History of Renaissance Philosophy, pp. 236-63, esp. pp. 247-63; Paul O. Kristeller, Eight Philosophers of the Italian Renaissance (Stanford: Stanford University Press, 1964). More generally on the different types of philosophers in this period, see Paul Richard Blum, Philosophenphilosophie und Schulphilosophie. Typen des Philosophierens in der Neuzeit (Stuttgart: Franz Steiner Verlag, 1998).

51. Stuart Brown, "Renaissance Philosophy Outside Italy," in G. H. R. Parkinson, The Renaissance and Seventeeth-Century Rationalism, pp. 70-103, at p. 75.

52. On the conflict with Scaliger, see especially Ian Maclean, "The Interpretation of Natural Signs: Cardano's De Subtilitate vs. Scaliger's Exercitationes," in Occult and Scientific Mentalities in the Renaissance, ed. Brian Vickers (Cambridge: Cambridge University Press, 1984), pp. 231-52; on Cardano's reception see Kristian Jensen, "Cardanus and his readers in the sixteenth century," and Ian Maclean, "Cardano and his publishers 1534-1663," in Girolamo Cardano, Philosoph, Naturforscher, Arzt, ed. Eckhard Kessler (Wiesbaden: Harrossowitz, 1994). On Cardano's work in astrology and medicine see, respectively, Anthony Grafton, Cardano's Cosmos: The Worlds and Works of a Renaissance Astrologer (Cambridge, Mass.: Harvard University Press, 1999) and Nancy G. Siraisi, The Clock and the Mirror: Girolamo Cardano and Renaissance Medicine (Princeton, N.J.: Princeton University Press, 1997).

53. See Luigi Firpo, "The Flowering and Withering of Speculative Philosophy—Italian Philosophy and the Counter Reformation: The Condemnation of Francesco Patrizi," in The Late Italian Renaissance, 1525-1630, ed. Eric Cochrane (London: Macmillan, 1970), pp. 266-86, at p. 278. For recent work on Patrizi, see Luc Deitz, "Space, Light, and Soul in Francesco Patrizi's Nova de universis philosophia (1591)," in Natural Particulars: Nature and the Disciplines in Renaissance Europe, pp. 139-69 and the literature cited there.

54. See also D. P. Walker, Spiritual and Demonic Magic (Notre Dame, Ind.:

University of Notre Dame Press, 1975), pp. 189-92 and, for the most recent treatment, Martin Mulsow, Frühneuzeitliche Selbsterhaltung: Telesio und die Naturphilosophie der Renaissance (Tübingen: Max Niemeyer Verlag, 1998).

55. See John M. Headley, Tommaso Campanella and the Transformation of the World (Princeton, N.J.: Princeton University Press, 1997), pp. 162-3, 104ff. On Campanella's practice of astral magic with the pope, see D. P. Walker, Spiritual and Demonic Magic, chap. 7. On the French reception of Campanella, see Michel-Pierre Lerner, Tommaso Campanella en France au XVIIe siècle (Naples: Bibliopolis, 1995).

56. For the most recent work, see Hilary Gatti, Giordano Bruno and Renaissance Science (Ithaca, N.Y.: Cornell University Press, 1999), esp. chaps. 6-8.

57. Kraye, "The Philosophy of the Italian Renaissance," pp. 49-50. On Bruno’s trial, see Luigi Firpo, Il processo di Giordano Bruno, ed. Diego Quaglioni (Rome: Salerno, 1993). John Bossy argues that Bruno actively worked to undermine the Catholic missions in England while he was there in the 1580s and wrote virulently against the papacy, but these activities, performed under a pseudonym, were not known to the Inquisitors and did not play a role in his trial; see John Bossy, Giordano Bruno and the Embassy Affair (New Haven, Conn.: Yale University Press, 1991), esp. pp. 179-80. For a recent overview of the controversies surrounding Bruno, see Michele Ciliberto, "Giordano Bruno tra mito e storia," I Tatti

Studies, 7 (1997), 175-90.

58. See Charles B. Schmitt, "Aristotle as a Cuttlefish: The Origin and Development of a Renaissance Image," Studies in the Renaissance, 12 (1965), 60-72.

59. See for example the eclecticism of Jean Bodin, as discussed in Blair, The Theater of Nature, pp. 107-15.

60. Replacing earlier problematic editions there is now Syncretism in the West: Pico's 900 Theses (1486). The Evolution of Traditional Religious and Philosophical Systems, ed. and trans. S. A. Farmer (Tempe, Ariz.: Medieval and Renaissance Texts and Studies, 1998). See also Charles B. Schmitt, "Perennial Philosophy: from Agostino Steuco to Leibniz," Journal of the History of Ideas, 27 (1966), 505-32; and Wilhelm Schmidt-Biggemann, Philosophia Perennis: Historische Umrisse abendländischer Spiritualität in Antike, Mittelalter und Früher Neuzeit (Frankfurt: Suhrkamp, 1998).

61. See Richard H. Popkin, The History of Scepticism from Erasmus to Spinoza, rev. ed. (Berkeley: University of California Press, 1979); José R. Maia Neto, "Academic Skepticism in Early Modern Philosophy," Journal of the History of Ideas, 58 (1997), 199-220; Zachary Sayre Schiffman, On the Threshold of Modernity: Relativism in the French Renaissance (Baltimore: Johns Hopkins University Press, 1991); Francisco Sanchez, That Nothing Is Known, ed. Elaine Limbrick, trans. Douglas Thomson (Cambridge: Cambridge University Press, 1984);

Agrippa von Nettesheim, Of the Vanitie and Uncertaintie of Artes and Sciences [first published in Latin, 1526], ed. Catherine Dunn (Northridge: California State University Press, 1974).

62. Petrarch, "On His Own Ignorance and That of Many Others," trans. Hans Nachod, in The Renaissance Philosophy of Man, ed. Ernst Cassirer et al. (Chicago: University of Chicago Press, 1948), p. 101.

63. The most extensive condemnations were those of Etienne Tempier, bishop of Paris, in 1277. For a recent discussion see J. M. M. H. Thijssen, "What Really Happened on 7 March 1277? Bishop Tempier's Condemnation and Its Institutional Context," in Texts and Contexts in Ancient and Medieval Science: Studies on the Occasion of John E. Murdoch's Seventieth Birthday, ed. Edith Sylla and Michael McVaugh (Leiden: Brill, 1997), pp. 84-105.

64. The role of religious objections to Aristotle has been well studied for the medieval period, but much less so for the later one. For a recent account of Renaissance philosophy that brings the later religious anti-Aristotelianism to the fore, see Stephen Menn, "The Intellectual Setting," in The Cambridge History of Seventeenth-Century Philosophy, ed. Garber and Ayers, 1: 33-86.

65.John Murdoch concludes of the late medieval period that, “in a very important way natural philosophy was not about nature”; the observation applies equally well to most traditional natural philosophy in the early modern period, which perpetuated the speculative discussions typical of medieval science. See John Murdoch, "The Analytic Character of Late Medieval Learning: Natural Philosophy without Nature," in Approaches to Nature in the Middle Ages, ed. Lawrence D. Roberts (Binghamton, N.Y.: Center for Medieval and Renaissance Studies, 1982), pp. 171-213, at p. 174.

66. See Martin L. Pine, Pietro Pomponazzi: Radical Philosopher of the Renaissance (Padua: Editrice Antenore, 1986).

67. Kraye, "The Philosophy of the Italian Renaissance," p. 42. For new documents concerning a 1604 denunciation of Cremonini on the grounds that he did not teach the immortality of the soul, see Antonino Poppi, ed., Cremonini e Galilei inquisiti a Padova nel 1604: nuovi documenti d'archivio (Padua: Antenore, 1992); on his thought more generally see, most recently, Heinrich C. Kuhn, Venetischer Aristotelismus im Ende der aristotelischen Welt. Aspekte der Welt und des Denkens des Cesare Cremonini (1550-1631) (Frankfurt: Peter Lang, 1996); and Cesare Cremonini (1550-1631). Il suo pensiero e il suo tempo (Documenti e Studi, 7) (Cento: Baraldi, 1990).

68. On the role of metaphysics in supplying philosophical demonstrations of religious tenets, see Charles Lohr, "Metaphysics," in The Cambridge History of Renaissance Philosophy, pp. 537-638, esp. pp. 614ff.

69. As discussed in Mercer, "The Vitality and Importance of Early Modern Aristotelianism," pp. 41-2.

70. Schmitt, Aristotle and the Renaissance, p. 11; and more generally, Heikki Mikkeli, An Aristotelian Response to Renaissance Humanism: Jacopo Zabarella on the Nature of Arts and Sciences (Helsinki: SHS, 1992). For recent work on early modern treatments of method see Daniel A. di Liscia et al., Method and Order in Renaissance Philosophy of Nature. The Aristotle Commentary Tradition (Aldershot: Ashgate, 1997).

71. See Leonardo Taran, "Amicus Plato sed magis amica veritas. From Plato to Aristotle to Cervantes," Antike und Abendland, 30 (1984), 93-124; and Henry Guerlac, "Amicus Plato and Other Friends," Journal of the History of Ideas, 39 (1978), 627-33.

72. Charles H. Lohr, "The Sixteenth-Century Transformation of the Aristotelian Natural Philosophy," in Aristotelismus und Renaissance: In memoriam Charles Schmitt, ed. Eckhard Kessler, Charles H. Lohr, and Walter Sparn (Wiesbaden: Harrassowitz, 1988), pp. 89-99, at pp. 90-91.

73. See Kusukawa, The Transformation of Natural Philosophy, p. 175; see also Charlotte Methuen, "The Teaching of Aristotle in Late Sixteenth-century Tübingen," in Philosophy in the Sixteenth and Seventeenth Centuries: Conversations with Aristotle, ed. Constance Blackwell and Sachiko Kusukawa (Aldershot: Ashgate, 1999), pp. 189-205.

74. Lambert Daneau, Physica Christiana (Geneva: Petrus Santandreanus, 1576); on

this agenda more generally see Ann Blair, "Mosaic Physics and the Search for a Pious Natural Philosophy in the Late Renaissance," Isis, 91 (2000), 32-58.

75. On Daneau see Olivier Fatio, Méthode et théologie: Lambert Daneau et les débuts de la scolastique réformée (Geneva: Droz, 1976) and Max Engammare, "Tonnerre de Dieu et 'courses d'exhalations encloses es nuées': Controverses autour de la foudre et du tonnerre au soir de la Renaissance," in Sciences et religions de Copernic à Galilée (1540-1610) (Rome: Ecole Française de Rome, 1999), pp. 161-81. More generally the latter volume contains a rich sampling of current work on science and religion in the sixteenth and early seventeenth centuries.

76. For a detailed study of the citation patterns of a Calvinist professor see Joseph Freedman, European Academic Philosophy in the Late Sixteenth and Seventeenth Centuries: The Life, Significance, and Philosophy of Clemens Timpler (1563/4-1624), 2 vols. (Hildesheim: Georg Olms, 1988). Zabarella is the modern author most cited in Timpler's natural philosophy; see Freedman, 1: 276 and n. 180 at 2: 642.

77. "Videbam physicam disciplinam, si recte pro sua dignitate tractaretur, ad sacram Theologiam plurimum omnino habere momenti, et ad Dei pleniorem cognitionem: neque ad Dei tantum cognitionem, verumetiam ad Dei excitandum amorem, mirum in modum conducere: quae duo (nempe Dei cognitio et amor) omnium debent esse honestorum studiorum ultimus atque praecipuus finis." Frans Titelmans,

Compendium philosophiae naturalis (Paris: Michael de Roigny, 1582; 1st publ. 1542), p. 4. On this work see Schmitt, "The Rise of the Philosophical Textbook," pp. 795-6.

78. For the latest discussion of the vexed question of the existence of atheists in this period, see Michael Hunter and David Wootton, eds., Atheism from the Reformation to the Enlightenment (Oxford: Clarendon Press, 1992).

79. For a brief discussion of the irenic role of natural philosophy, a topic that warrants further study, see my Theater of Nature, pp. 26 and 147-8.

80. For a lucid presentation of the historiography and history of Jewish attitudes toward natural philosophy in this period, see David B. Ruderman, Jewish Thought and Scientific Discovery in Early Modern Europe (New Haven, Conn.: Yale University Press, 1995), esp. chap. 2 and pp. 370-71.

81. Noah Efron, "Irenism and Natural Philosophy in Rudolfine Prague: The Case of David Gans," Science in Context, 10 (1997), 627-49. See also André Neher, Jewish Thought and the Scientific Revolution of the Sixteenth Century: David Gans (1541-1613) and his Times, trans. David Maisel (Oxford: Oxford University Press, 1986).

82. Ruderman, Jewish Thought and Scientific Discovery, chap. 3.

83. For an example of the interactions of kabbalah and natural philosophy, see David B. Ruderman, Kabbalah, Magic, and Science: The Cultural Universe of a Sixteenth-Century Jewish Physician (Cambridge, Mass.: Harvard University Press, 1988). A

recent volume on seventeenth-century Jewish thought makes no mention of scientific topics: see Jewish Thought in the Seventeenth Century, ed. Isadore Twersky and Bernard Septimus (Cambridge, Mass.: Harvard University Press, 1987).

84. See for example E. G. R. Taylor, The Mathematical Practitioners of Tudor and Stuart England (Cambridge: Cambridge University Press, 1967).

85. See the translation of his Nova Scientia [1537] in Mechanics in Sixteenth-Century Italy, ed. and trans. Stillman Drake and I. E. Drabkin (Madison: University of Wisconsin Press, 1969).

86. Bernard Palissy, Discours admirable des eaux et fontaines (Paris: M. le Jeune, 1580). On Palissy in particular and on this theme more generally, see Paolo Rossi, Philosophy, Technology, and the Arts in the Early Modern Era, ed. Benjmain Nelson, trans. Salvator Attanasio (New York: Harper and Row, 1970), pp. 1-4.

87. See Robert Westman, "The Melanchthon Circle, Rheticus, and the Wittenberg Interpretation of the Copernican Theory," Isis, 66 (1975), 165-93.

88. For example, one professor at Paris who had rapidly dismissed Copernicanism in a physics course of 1618-19 gave more careful consideration to the objections and possible responses to them in a later course of 1628; see Ann Blair, "The Teaching of Natural Philosophy in Early Seventeenth-Century Paris: The Case of Jean Cécile Frey," History of Universities, 12 (1993), 95-158, at p. 126. One can find a similar

discussion of arguments and counter-arguments with no final conclusion in a physics lecture by Caspar Barlaeus at the University of Amsterdam in 1636; see Paul Dibon, La philosophie néerlandaise au siècle d'or, vol. 1: L'Enseignement philosophique dans les universités à l'époque précartésienne (1575-1650) (Amsterdam: Elsevier, 1954), p. 234.

89. For the case of France and especially Paris, see Laurence Brockliss, "Copernicus in the University: The French Experience," in New Perspectives on Renaissance Thought: Essays in the History of Science, Education, and Philosophy, ed. John Henry and Sarah Hutton (London: Duckworth, 1990), pp. 190-213, esp. pp. 191-7; on other Catholic contexts, including Southern France, Italy, Spain, and Portugal, see W. G. L. Randles, The Unmaking of the Medieval Christian Cosmos, 1500-1760. From Solid Heavens to Boundless Aether (Aldershot: Ashgate, 1999), chaps. 7-8. On the lifting of the ban, see Pierre-Noël Mayaud, La condamnation des livres coperniciens et sa révocation à la lumière de documents inédits (Rome: Editrice Pontificia, 1997).

90. Wolfgang Rother, "Zur Geschichte der Basler Universitätsphilosophie im 17. Jahrhundert," History of Universities, 2 (1982), 153-191, at p. 169.

91. On the problem of Biblical interpretation posed by Copernicanism, see Richard Blackwell, Galileo, Bellarmine, and the Bible (Notre Dame, Ind.: University of Notre Dame Press, 1991); and Gary B. Deason, "John Wilkins and Galileo Galilei:

Copernicanism and Biblical Interpretation in the Protestant and Catholic Traditions," in Probing the Reformed Tradition: Historical Essays in Honor of Edward A. Dowey Jr, ed. Elsie Anne McKee and Brian G. Armstrong (Louisville, Ky: Westminster/John Knox Press, 1989). See also Ann Blair, "Tycho Brahe's Critique of Copernicus and the Copernican System," Journal of the History of Ideas, 51 (1990), 355-77.

92. See Roger Ariew, "The Theory of Comets at Paris 1600-50," Journal of the History of Ideas, 53 (1992), 355-72.

93. See Roger Ariew, "Galileo's Lunar Observations in the Context of Medieval Lunar Theory," Studies in History and Philosophy of Science, 15 (1984), 213-26.

94. Gilbert Jacchaeus, Institutiones physicae, 1.4, 4th ed. (Schleusingen: Petrus Schmit, 1635), p. 13, as quoted in Reif, Natural Philosophy in Some Early Seventeenth-Century Scholastic Textbooks, p. 66.

95. For an example, see Wilhelm Scribonius, Physica et sphaerica doctrina (Frankfurt: Palthenius, 1600), p. 189ff.

96. Dainville, La géographie des humanistes, pp. 25-35.

97. Ibid., pp. 343-74.

98. See Blair, "The Teaching of Natural Philosophy," esp. pp. 124-7.

99. See Peter Dear, Discipline and Experience: The Mathematical Way in the Scientific Revolution (Chicago: University of Chicago Press, 1995), chap. 2.

100. Stephen Pumfrey, "Neo-Aristotelianism and the Magnetic Philosophy," in New Perspectives on Renaissance Thought, pp. 177-89, esp. p. 184.

101. Dear, Discipline and Experience, pp. 33-42.

102. Recent historiography on the Jesuits stresses the diversity of Jesuit involvement in science, notably in The Jesuits: Cultures, Sciences, and the Arts 1540-1773, ed. John W. O'Malley et al. (Toronto: University of Toronto Press, 1999), particularly the articles by Rivka Feldhay, Michael John Gorman, Steven Harris, Florence Hsia, and Marcus Hellyer. See also Steven J. Harris, "Confession-building, Long-Distance Networks, and the Organization of Jesuit Science," Early Science and Medicine, 1 (1996), 287-318 and the rest of this special issue on "Jesuits and the Knowledge of Nature"; Rivka Feldhay, "Knowledge and Salvation in Jesuit Culture," Science in Context, 1 (1987), 195-213.

103. See, for example, the case of Leiden as discussed in Leiden University in the Seventeenth Century, ed. Th. H. Lunsing Scheurleer and G. H. M. Posthumus Meyjes (Leiden: Brill, 1975); or that of Altdorf, on which see Olaf Pedersen, "Tradition and Innovation," in A History of the University in Europe, pp. 451-88, on p. 473. On botanical gardens at Italian universities, see Paula Findlen, Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy (Berkeley: University of California Press, 1994), pp. 256-61.

104. A convenient list of English professorships in the sciences can be found in

Robert Merton, Science, Technology, and Society in Seventeenth Century England (Atlantic Highlands, N.J.: Humanities Press, 1970), p. 29.

105. Lesley B. Cormack, Charting an Empire: Geography at the English Universities, 1580-1620 (Chicago: University of Chicago Press, 1997), pp. 27ff.

106. For a detailed study of the student experience at Oxford and Cambridge, see Mordechai Feingold, The Mathematicians' Apprenticeship: Science, Universities, and Society in England 1560-1640 (Cambridge: Cambridge University Press, 1984); for a general reassessment of the role of universities in the Scientific Revolution, see John Gascoigne, Science, Politics, and Universities in Europe 1600-1800 (Aldershot: Ashgate, 1998).

107. See for example the complaints discussed in Mercer, "The Vitality and Importance of Early Modern Aristotelianism," pp. 34-8.

108. For the text of the Jesuit injunction to follow Aristotle in natural philosophy among other fields, see Roger Ariew, "Descartes and Scholasticism: The Intellectual Background to Descartes' Thought," in The Cambridge Companion to Descartes, ed. John Cottingham (Cambridge: Cambridge University Press, 1992), pp. 58-90, on pp. 64-5. For a French royal decree of 1671 calling for no other doctrine to be taught than "the one decreed by the rules and statutes of the university," see Descartes' Meditations: Background Source Materials, ed. Roger Ariew et al. (Cambridge: Cambridge University Press, 1998), p. 256.

109. On Claude Bérigard (d. 1663/64), who taught at Pisa 1627-39, then at Padua until 1663, and other examples of Italian professors straying from the official curriculum, see Brendan Dooley, "Social Control and the Italian Universities: From Renaissance to Illuminismo," Journal of Modern History, 61 (1989), 205-39, for example, p. 229.

110. Edward Grant, "Ways to Interpret the Terms 'Arisotelian' and 'Aristotelianism' in Medieval and Renaissance Natural Philosophy," History of Science, 25 (1987), 335-58.

111. Roger Ariew, "Aristotelianism in the Seventeenth Century," in Routledge Encyclopedia of Philosophy, ed. Edward Craig, vol. 1 (London: Routledge, 1998), pp. 386-93, at p. 386.

112. As discussed in more detail in Roger Ariew and Alan Gabbey, "The Scholastic Background," in The Cambridge History of Seventeenth-Century Philosophy, pp. 429-32.

113. Theophraste Bouju, Corps de toute la philosophie divisé en deux parties, vol. 1 (Paris: Charles Chastellain, 1614), ch. 18, pp. 405-8, as cited in Ariew, "Theory of Comets at Paris, 1600-1650," Journal of the History of Ideas, 53 (1992), 355-72, at p. 360. For Bouju's opinions on the void and place, see Ariew and Gabbey, "The Scholastic Background," pp. 436, 438. As a commentator on Aristotle active outside the universities, Bouju was particularly free from traditional interpretive constraints.

114. See Siraisi, The Clock and the Mirror, pp. 56-8 and 138-42.

115. This is also the conclusion I reached in confronting the statements made about Aristotle with the actual reliance on Aristotelian categories in the cases of the explicitly anti-Aristotelian, but nonetheless traditionalist, Jean Bodin and the explicitly Aristotelian, but innovative, Jean-Cécile Frey; see my "Tradition and Innovation in Early Modern Natural Philosophy: Jean Bodin and Jean-Cécile Frey," Perspectives on Science, 2 (1994), 428-54.

116. For the most recent literature on the reception of Paracelsus see Heinz Schott and Ilana Zinguer, eds., Paracelsus und seine internationale Rezeption in der frühen Neuzeit: Beiträge zur Geschichte des Paracelsismus, (Leiden: Brill, 1998).

117. I am drawing here on the analysis of Daniel Garber, "On the Front Lines of the Scientific Counter-Revolution: Defending Aristotle Paris-Style," (paper presented at a conference on "Tradition and Novelty: Cultural and Regional Considerations in the Competition between the Old and the New Science in the Seventeenth Century," Chicago Humanities Institute, April 1994); I am grateful to the author for a copy of this paper, which will appear as part of his forthcoming book, Aristotelianism and Anti-Aristotelianism in Paris, 1620-1650. Jean-Baptiste Morin vividly describes the scene of the 1624 thesis defense before setting out to refute the theses himself in Refutation des thèses erronées d'Anthoine Villon dit le soldat philosophe et Estienne de Claves medecin chimiste (Paris: printed by the author, 1624).

118. See for example the refutation of criticisms of Aristotle on points large and small in Jean-Cécile Frey's Cribrum philosophorum [1628] as discussed in my "Teaching Natural Philosophy in Early Seventeenth-Century Paris," pp. 117-20.

119. Marin Mersenne, La vérité des sciences, 1 [1625] (facsimile Stuttgart-Bad Cannstatt: Friedrich Frommann Verlag, 1969), ch. 5, pp. 109-10. On Mersenne see Peter Dear, Mersenne and the Learning of the Schools (Ithaca, N.Y.: Cornell University Press, 1988); on the rather austere order of Minims, which nonetheless produced a number of important French philosophers in the seventeenth century, see P. J. S. Whitmore, The Order of Minims in 17th-century France (The Hague: Martinus Nijhoff, 1967).

120. See for example the student notebooks surviving from the Academia Cervariensis, or University of Cervera, which replaced the University of Barcelona from 1714 to 1821, and which are preserved at the Biblioteca de Catalunya, Barcelona: e.g., Jaume Puig, "Tractatus in octo libros physicos Aristotelis," MS 1647 (1741-42); Joseph Vallesca, "Cursus aristotelicus," MS 2521 (18th); Josephus Osset, "Philosophiae novo-antiquae institutiones," MS 602 (1779), in which, despite the title, one still finds a defense of Aristotle, notably against the Stoics and Plato. This very late Aristotelianism, which may well also be found elsewhere, would certainly be worth charting systematically.

121. Lohr, "Renaissance Latin Aristotle Commentaries, A-B," p. 230.

122. On della Porta see William Eamon, Science and the Secrets of Nature: Books of Secrets in Medieval and Early Modern Culture (Princeton, N.J.: Princeton University Press, 1994), chap. 6; on Cesi's project, see Brendan Dooley, ed. and trans., Italy in the Baroque. Selected Readings (New York: Garland Publishing, 1995), pp. 23-37.

123. For the German societies, see R. W. J. Evans, "Learned Societies in Germany in the 17th Century," European Studies Review, 7 (1977), 129-52; Der Akademiegedanke im 17. und 18. Jahrhundert, ed. Fritz Hartmann and Rudolf Vierhaus (Bremen and Wolfenbüttel: Jacobi Verlag, 1977), particularly R. Winau, "Zur Frühgeschichte der Academia Curiosorum," pp. 117-38; and Pedersen, "Tradition and Innovation," p. 484.

124. See Ayval Ramati, "Harmony at a Distance: Leibniz's Scientific Academies," Isis, 87 (1996), 430-52, esp. pp. 449-51; and Leibniz und seine Akademie. Ausgewählte Quellen zur Geschichte der Berliner Sozietät der Wissenschaften 1697-1716, ed. Hans-Stephan Brather (Berlin: Akademie Verlag, 1993).

125. On the antecedents to these two societies, see respectively Charles Webster, The Great Instauration. Science, Medicine, and Reform 1626-60 (New York: Holmes and Meier, 1975); and Harcourt Brown, Scientific Organizations in Seventeenth-Century France, 1620-80 (New York: Russell and Russell, 1967).

126. Garber, "On the Front-Lines of the Scientific Counter-Revolution."

127. Howard M. Solomon, Public Welfare, Science, and Propaganda in Seventeenth-Century France: The Innovations of Théophraste Renaudot (Princeton, N.J.: Princeton University Press, 1972), pp. 72-3; and Simone Mazauric, Savoirs et Philosophie à Paris dans la première moitié du XVIIe siècle: les conférences du bureau d'adresse de Théophraste Renaudot (1633-42) (Paris: Publications de la Sorbonne, 1997).

128. As described in Adrien Baillet, La Vie de Monsieur Descartes [1691], 1.14 (New York: Garland, 1987), pp. 160-65.

129. Pintard, Le libertinage érudit, pp. 42-3. On Basso see Christoph Luethy, "Thoughts and Circumstances of Sébastien Basson. Analysis, Micro-History, Questions," in Early Science and Medicine, 2 (1997), 1-73.

130. See Daniel Garber, John Henry, Lynn Joy, and Alan Gabbey, "New Doctrines of Body and its Powers, Place, and Space," in The Cambridge History of Seventeenth-Century Philosophy, 1: 553-623; and Stephen Clucas, "The Atomism of the Cavendish Circle: A Reappraisal," The Seventeenth Century, 9 (1994): 247-73, which questions the notion of "atomism" as a unified doctrine.

131. E. J. Dijksterhuis, The Mechanization of the World Picture, Pythagoras to Newton (Princeton, N.J.: Princeton University Press, 1961), III.V.C: "The defection from Aristotelianism," p. 282.

132. See the discussion of Harvard University in William R. Newman, Gehennical

Fire. The Lives of George Starkey, an American Alchemist in the Scientific Revolution (Cambridge, Mass.: Harvard University Press, 1994), esp. pp. 20-32.

133 See Clucas, "The Atomism of the Cavendish Circle," pp. 251-52. On Paracelsus and the notion of "seeds," see Walter Pagel, Paracelsus, 2nd ed.(Basel: Karger, 1982), p. 85.

134. Garber, Henry, Joy, and Gabbey, "New Doctrines of Body," pp. 569-73. See Gassendi, Exercitationes paradoxicae adversus Aristoteleos [1624], ed. and trans. Bernard Rochot (1959). See Margaret Osler, "Baptizing Epicurean Atomism: Pierre Gassendi on the Immortality of the Soul," in Religion, Science, and Worldview: Essays in Honor of Richard S. Westfall, ed. Margaret J. Osler and Paul Lawrence Farber (Cambridge: Cambridge University Press, 1985), pp. 163-84; and, more generally, Lynn Joy, Gassendi the Atomist: Advocate of History in an Age of Science (Cambridge: Cambridge University Press, 1987).

135. On Descartes' authorial strategies see Jean-Pierre Cavaillé, "'Le plus éloquent philosophe des derniers temps': Les stratégies d'auteur de René Descartes," Annales. Histoire, Sciences Sociales, 2 (1994), 349-67.

136. For a more detailed comparison of the reception of the two thinkers, see Thomas Lennon, The Battle of Gods and Giants: The Legacies of Descartes and Gassendi 1655-1715 (Princeton, N.J.: Princeton University Press, 1993) and Laurence Brockliss, "Descartes, Gassendi, and the Reception of the Mechanical Philosophy in the French Colleges de Plein Exercice 1640-1730," Perspectives on

Science, 3 (1995), 450-79, and more generally this entire journal issue entitled Descartes versus Gassendi.

137. These claims are inevitably exaggerated; for a study of the legacy of scholasticism in Descartes, see Etienne Gilson, Etudes sur le rôle de la pensée médiévale dans la formation du système cartésien (Paris: Vrin, 1930); and Roger Ariew, Descartes and the Last Scholastics (Ithaca, N.Y.: Cornell University Press, 1999).

138. The term was coined in 1662 as a pejorative by the Cambridge Platonist Henry More; see Brian Copenhaver, "The Occultist Tradition and its Critics," in The Cambridge History of Seventeenth-Century Philosophy, 1: 485.

139. Christiaan Huygens, appendix to the letter of 26 February 1693 to Bayle, in Oeuvres, 10.403, as quoted in Dijksterhuis, The Mechanization of the World Picture, p. 408.

140. Regius maintained, for example, that a human being is not a substantial unity but only an ens per accidens; Descartes commented that "you could hardly say anything more offensive." See Descartes, Oeuvres, 2.460, ed. Adam et Tannery, as quoted in Geneviève Rodis-Lewis, "Descartes' Life and the Development of His Philosophy," in The Cambridge Companion to Descartes, pp. 43 and 55. Recent scholarship has emphasized the independence of Regius from Descartes; see Paul Dibon, "Der Cartesianismus in den Niederlanden," in Die Philosophie des 17.

Jahrhunderts, ed. Jean-Pierre Schobinger, 4 vols. (Basel: Schwabe, 1992), 2: 357-8.

141. As quoted in Nicholas Jolley, "The Reception of Descartes' philosophy," in The Cambridge Companion to Descartes, p. 395. On this "quarrel of Utrecht," see La querelle d'Utrecht: René Descartes et Martin Schoock, ed. Theo Verbeek (Paris: Impressions Nouvelles, 1988).

142. Theo Verbeek, Descartes and the Dutch. Early Reactions to Cartesian Philosophy, 1637-1650 (Carbondale and Edwardsville, Ill.: Southern Illinois University Press, 1992), pp. 85-6. For a rich history of the reception of Cartesianism and Copernicanism in the Low Countries, see Rienk Vermij, The Calvinist Copernicans: the Reception of the New Astronomy in the Dutch Republic 1575-1750 (Amsterdam: Koninklijke Nederlandse Akademie van Wetenschappen, 2002).

143. See Roger Ariew, "Damned If You Do: Cartesians and Censorship, 1663-1706," Perspectives on Science, 2 (1994), 255-74.

144. See Tad Schmalz, "What Has Cartesianism To Do with Jansenism?" Journal of the History of Ideas, 60 (1999), 37-56; and Brockliss, "Descartes, Gassendi, and the Reception of the Mechanical Philosophy," p. 473.

145. On Rohault, his successor Pierre-Sylvain Régis and Malebranche, see P. Mouy, Le développement de la physique cartésienne, 1646-1712 (Paris: Vrin, 1934), esp. pp. 108-16; on his textbook see G. Vanpaemel, "Rohault's 'Traité de physique' and the Teaching of Cartesian Physics," Janus, 71 (1984), 31-40.

146. See Michael Heyd, Between Orthodoxy and the Enlightenment: Jean-Robert Chouet and the Introduction of Cartesian Science in the Academy of Geneva (The Hague: Martinus Nijhoff, 1982), pp. 116-17.

147. See Roger Ariew and Marjorie Grene, "The Cartesian Destiny of Form and Matter," Early Science and Medicine, 2 (1997), 302-25, on pp. 321-2.

148. Brockliss, "Descartes, Gassendi, and the Reception of the Mechanical Philosophy," p. 469; more generally, see Dennis Des Chene, Physiologia: Natural Philosophy in Late Aristotelian and Cartesian Thought (Ithaca N.Y.: Cornell University Press, 1996).

149. See Francesco Trevisani, Descartes in Germania: La ricezione del cartesianesimo nella Facoltà filosofica e medica di Duisburg (1652-1703) (Milan: Francoangeli, 1992), p. 13.

150. On Cartesianism in Italy, see Claudio Manzoni, I Cartesiani Italiani (1660-1760) (Udine: La Nuova Base, 1984); Mario Agrimi, "Descartes nella Napoli di fine Seicento," in Descartes: Il Metodo e i Saggi (Atti del Convegno per il 350o anniversario della pubblicazione del Discours de la méthode e degli Essais), ed. Giulia Belgioioso et al., 2 vols. (Florence: Istituto della Enciclopedia Italiana, 1990), 2: 545-86; Giulia Belgioioso, Cultura a Napoli e Cartesianesimo: Scritti su G. Gimma, p. M. Doria, C. Cominale (Galatina: Congedo Editore, 1992); "Philosophie aristotélicienne et mécanisme cartésien à Naples à la fin du XVIIe siècle," Nouvelles

de la République des Lettres, 1 (1995), 19-47; and the special issue of the Giornale Critico della Filosofia Italiana, 16 (1996).

151. Brockliss, "Descartes, Gassendi and the Reception of the Mechanical Philosophy," p. 464.

152. These transitions are described in Brockliss, French Higher Education.

153. Robert Hugh Kargon, Atomism in England from Hariot to Newton (Oxford: Clarendon Press, 1966), pp. 63 and 69.

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