Science and Religion

Ann Blair, Dept of History, Harvard University

contribution to the Cambridge History of Christianity, vol. 6: Re-Formation and Expansion, 1500-1660.

REVISED VERSION June 2004

Science and Religion

The period of religious transformations covered in this volume corresponds closely in time to a series of major scientific developments traditionally known as the "Scientific Revolution", which is commonly considered to extend from the publication of Copernicus' heliocentric thesis (in De Revolutionibus, 1543) to that of Newton's laws of physics (in the Principia, 1687).[i] In the course of these 150 years Aristotelian natural philosophy, which had been dominant since its introduction to the Latin West ca. 1200, came under attack in many quarters and gradually lost its hold on the curriculum. Various alternative authorities and new interpretations of nature were advanced, but by 1650 the new philosophy which had become dominant was a mechanical philosophy premised on the notion that all phenomena could be explained as particles of matter in motion, according to mathematical laws open to empirical−observation and experimentation. The historiography on the Scientific Revolution is vast.[ii] Alongside detailed studies of the central figures and texts of the Scientific Revolution, we have a rich array of studies which highlight the role of the social, cultural and intellectual contexts of these developments. Among these religion has long been and continues to be acknowledged as a particularly important factor.

The historiography on science and religion across the centuries predates the

professionalization of the history of science and has from the beginning singled out the early modern period for developments which were taken as paradigmatic both of conflict (the Galileo Affair) and of cooperation ("Protestantism and science"). Although recent work on the interactions between science and religion has moved away from such starkly articulated theses, the early modern period remains a particularly rich area of study.[iii] In the sixteenth and seventeenth centuries new developments in both religion and science undermined the solidity of the scholastic synthesis of Aristotelianism and medieval Christianity and triggered a wide range of new interactions.

The legacy of the Middle Ages

The scholastic synthesis of Aristotelianism and Christianity was made possible by the reception of Aristotelian philosophy into the newly founded universities of Europe during the 13th century. This reception was not unproblematic. The early teaching of Aristotle in the Latin West triggered a series of condemnations culminating in 1277 when the bishop of Paris Etienne Tempier condemned as impious 217 theses which he feared were being drawn from Aristotle.[iv] The condemnations of 1277 highlighted a number of points of tension between Aristotelian philosophy and Christian beliefs. Aristotle could be read as supporting both the eternity of the world and the mortality of the soul, although Thomas Aquinas skillfully averted conflict by arguing that Aristotle concluded that these points could not be decided from reason alone; without impugning reason or the authority of Aristotle, Aquinas argued that these human sources had to be supplemented with the authority of revelation, with its doctrines of Creation and of the immortality of the soul. The necessity of natural law was another major point of tension, which continued to surface in various forms even as Aristotelianism gave way to new philosophies in

the early modern period. The scholastic distinction between the absolute and the ordained power of God served to acknowledge both that God had the power to suspend the laws of nature and that in practice God chose to abide by them. This distinction legitimated the naturalistic study of God's ordained power without seeming to deny divine omnipotence.[v]

Thanks to these resolutions of points of conflict, developed by Thomas Aquinas among others, by 1325 Aristotle was fully entrenched in the curriculum of the arts faculty at the University of Paris and at most other universities. The institutional separation between the faculty of theology and the lower-ranked arts faculty gave philosophers a variable amount of independence from theological constraints, depending on the context. At Paris, the Sorbonne was powerful and philosophers abided by the condemnations of 1277. At the University of Padua, which had no theology faculty, but only a higher faculty of medicine, the philosophers enjoyed great independence and were noted for their radical Aristotelianism. This Paduan tradition survived into the sixteenth century, when it generated increasing ecclesiastical reaction. Pietro Pomponazzi (1462-1525), professor at Padua, concluded in his On the immortality of the soul (1516) 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 astrology and miracles.[vi] Even later in the century Cesare Cremonini (1550-1631) left un-Christianized 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, but he still retained his high-paying position at the University of Padua.[vii]

The opportunities for the institutional and intellectual independence to philosophers offered by some scholastic contexts were on the wane in the sixteenth century. Throughout the

sixteenth and seventeenth centuries natural philosophy was justified by religious motivations and informed by religious beliefs. Already at the Fifth Lateran Council (1512-17), the Church called on philosophers to play an active role in supporting religious doctrines and mandated philosophical demonstrations of the immortality of the soul, for example.[viii] The Reformers devised new curricula in which natural philosophy would serve the needs of religious doctrine. The post-Tridentine Catholic Church tightened its control on the religious orthodoxy of philosophical works through education on the one hand and the Inquisition and Index of Forbidden Books on the other. The impetus behind this renewed emphasis on the need for philosophy to be pious was not only religious in origin. The humanist movement was equally hostile to scholasticism and the perceived impieties of Aristotelianism. Petrarch (1304-74) mocked Aristotelianism as sterile and raised the classic Christian objections to Aristotle as articulated in 1277. Petrarch did not propose any philosophical alternatives to Aristotle, but he opened the way for others to do so, by objecting to an excessive reliance on Aristotle and Aristotelian method.[ix]

The Renaissance search for a pious philosophy

The humanists are well known for their efforts in bringing to light long-lost ancient texts. Among these there were ancient commentaries on Aristotle, which offered new and often critical perspectives on the Philosopher, but also texts from quite different philosophical traditions--particularly Stoic, Epicurean or Platonist--and doxographical works like Diogenes Laertius who reported the opinions of still other thinkers whose works were often no longer extant, such as the Pre-Socratics and the Pythagoreans. With all these alternatives available for study and imitation, Aristotle was no longer the only option; the long-standing religious objections to Aristotle could

be adduced to justify turning to other authorities who might seem more readily reconciled to Christian doctrines.

Marsilio Ficino (1433-99) championed Plato in developing a philosophical system complete enough to rival Aristotle's. In addition to voluminous translations of and commentaries on Plato, Ficino 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.[x] Ficino revived the arguments of St. Augustine in claiming that Plato's teachings on the individual immortality of the soul and on the creation of the world by a divine Demiurge made his philosophy more easily reconciled with Christianity. But the fit was not perfect, given Plato's belief in the transmigration of souls and the fact that the creation described in the Timaeus was not a creation ex nihilo, but rather from pre-existing matter. Platonic philosophy remained an option which appealed to a few thinkers like Symphorien Champier in France (ca. 1470-1539) or Jakob Boehme in Germany (1575-1624), down to the "Cambridge Platonists" Henry More (1614-87) and Ralph Cudworth (1617-88) who saw Platonism as a weapon against materialist interpretations of the mechanical philosophy.[xi] But the renewed emphasis on traditional orthodoxy in the Counter-Reformation Church resulted in the condemnation of the writings of Francesco Patrizi, for whom professorships in Platonic philosophy had been founded in Ferrara (1578) and Rome (1592), and the subsequent suppression of these positions by Robert Bellarmine who concluded that Platonism was more dangerous to Christianity than Aristotelianism.[xii]

Another scientific authority brought to the fore by the humanist movement was Lucretius, whose De natura rerum presented the Epicurean theory that the natural world is formed by the random movement and coalescence of atoms. Although Epicureanism continued to be associated

with immorality and impiety in the minds of many, Lucretius found a Christianizing champion in the French Oratorian Pierre Gassendi (1592-1655). Against Lucretius, Gassendi maintained that atoms were divinely created and endowed with motion by God and introduced angels and rational souls to complement the materialistic structure of the world. Gassendi concluded that his system was more pious than Aristotle's, because, among other virtues, it could account better for the transformation involved in the Eucharist.[xiii] Although Gassendi's particular type of atomism did not find many followers, his arguments smoothed the way for the acceptance of Descartes' mechanical philosophy, which, despite differences on various specifics, also rested on the assumption that the world can be explained as particles of matter in motion.

The Stoics appealed to Justus Lipsius who applied them not only to political but also to natural philosophy, again with the claim that the results were more pious than Aristotelianism.[xiv] The Pre-Socratic philosophers, known for their naturalism, were also used as the basis for "new philosophies" which proclaimed their superior piety. For example Bernardino Telesio (1509-1588) explained the natural world as the interaction between the two principles of hot and cold and Christianized his system by introducing a universal spirit of divine origin which infused the world. Tommaso Campanella (1568-1639), a disciple of Telesio, carried the idea of the world-spirit to a pansensist extreme of envisioning the whole universe as a living animal in which God was omnipresent and immanent. Nature was thus full of correspondences and divine messages which the natural philosopher could interpret, especially through astrology. But neither of these claims to piety seemed convincing to the post-Tridentine Church: Telesio's works were condemned posthumously in 1593 and Campanella spent most of 30 years in Italian jails and fled to France after his release in 1634.[xv]

Amid the plethora of philosophical experimentation unleashed by the Renaissance a

different strategy was to turn not to ancient philosophical authorities, but rather to religious inspiration and the Bible to ground a truly pious natural philosophy. Theophrastus Bombastus von Hohenheim, who styled himself "Paracelsus" for surpassing the ancient medical encyclopedist Celsus, claimed support from divine inspiration as well as empirical observation for his rejection of the traditional medical synthesis of Aristotle and Galen in favor of chemical remedies. Paracelsus was held in contempt by many throughout the early modern period and associated, at times unfairly, with dissolute habits, heresy (Arianism) and magical activities.[xvi] Nonetheless his writings, published from manuscripts gathered by followers after his death, elicited an enthusiastic following among non-conforming Protestant thinkers marginalized and radicalized by religious persecution, particularly in central Europe. These radical Paracelsians hailed his works as uniting both theological and philosophical truth by drawing on the lights of grace and of nature.[xvii] Millenarianism was often present in this utopian vision of religious and philosophical reformation, as it was in more mainstream Protestant thought.[xviii] Other, less radical attempts to ground a "most Christian" natural philosophy in biblical authority can be identified among thinkers, both Catholic and Protestant, who rejected Aristotelian explanations in favor of Biblical ones, attributing for example the origin of underground springs not to the condensation of watery vapors (as Aristotle explained) but to the oceans returning to their sources, as mentioned in Ecclesiastes 1:7.[xix] "Most Christian" strategies also included stressing the greatness of God as creator of such abundance and variety and, by contrast, the incompetence of reason to understand many natural phenomena. Confessing human ignorance in order better to praise God's glory remained a trait of religiously inclined natural theologies through the 17th century.[xx]

The explosion of new and often explicitly anti-Aristotelian philosophies in the Renaissance did not affect the standing of Aristotle as the authority of choice in traditional

pedagogical settings, such as schools and universities.[xxi] The Council of Trent elevated the Thomist synthesis of Aristotelianism and Christianity to the status of orthodox doctrine, so that in most Catholic institutions to deviate from Aristotle was to risk charges of impiety. The Jesuits in particular took an explicit oath of allegiance to Aristotle.[xxii] In Protestant universities, despite early attempts to find alternatives, Aristotle was soon established as the backbone of the curriculum.[xxiii] But as they packaged Aristotle for student consumption during the great educational expansion of the sixteenth century, both Catholics and Protestants placed Aristotelian natural philosophy in the context of Christian piety. One early textbook, by a Franciscan, intermingled philosophical presentations with psalms of praise to God. This format, which did not become the norm, is evidence of the uneasiness of the author at presenting Aristotle "straight up", especially to the broad and inexperienced readership targeted by an introductory textbook.[xxiv] Protestant textbooks, following the lead of Melanchthon, typically praised natural philosophy as an incitement to piety for revealing the benevolent providence of God.[xxv]

Whether they were Aristotelian or anti-Aristotelian, Renaissance natural philosophers proclaimed the piety of the study of nature. Natural philosophy offered justification for the existence, greatness and worship of God and could serve as a bulwark against impiety and atheism, which many contemporaries feared were on the rise.[xxvi] In some instances these statements may have been rhetorical reiterations of long-standard arguments; but most often religious motivations were central to inspiring the innovations of the anti-Aristotelian philosophies of the Renaissance.[xxvii] In any case pious motives and natural theological justifications long outlived both Aristotelianism and the "new philosophies" of the Renaissance grounded in other ancient authorities. As the mechanical philosophy of the 17th century

prevailed over these rivals, it too was couched in terms of Christian piety and praise of the greatness and providence of God.[xxviii] Christians of all confessions used natural theological arguments to justify the study of nature throughout the early modern period. Claims that one particular strand of Christianity, such as Lutheranism or Calvinism, was more open than others to the study of nature seem dubious; although less well known, Catholic natural theologies would also repay further study.[xxix]

Protestantism and Science

The historiography on science and religion originated during the early decades of the reception of Darwin when religious objections to the theory of evolution were intense. The debate is best known for the conflict thesis articulated bluntly by John William Draper, The History of the Conflict between Science and Religion (1874) and somewhat moderated by Andrew Dickson White, A History of the Warfare of Science with Theology in Christendom (1896). But those same decades elicited some equally classic historiographic statements about the cooperation of science and religion, including Pierre Duhem's argument that the condemnations of 1277 opened the way for the modern rejection of Aristotle and the claim that Protestantism was particularly favorable to science, first made by the Genevan naturalist Alphonse de Candolle.[xxx]

The notion of a special relationship between Protestantism and science had a long career, fueled by Max Weber's linkage of Protestantism with capitalism and articulated in most detail by Robert Merton in Science, Technology and Society in Seventeenth-Century England (1937-38). Over the following decades a remarkable number of scholars, most of them specialists of the 17th-century England, debated various formulations of the Merton thesis.[xxxi] These debates

helped to sharpen some historical categories, including the range of Protestantisms in 17th-century England, from strict Puritans often hostile to the study of nature to the Broad-Churchmen or latitudinarians whose desire to avoid religious controversy was characteristic of the core group of natural philosophers at the Royal Society. But the lengthy discussions about what features essential to Protestantism might have been favorable to science (which variously attributed to Protestantism greater rationalism, valuation of manual labor, optimism, rejection of received authority, of demons and the supernatural) no longer seem viable.[xxxii] On the one hand historians now tend to reject on principle essentialist characterizations of religious movements; in addition the much increased geographical range of historical studies, European and otherwise, has reinforced the dangers of generalizing from a particular case like 17th-century England. On the other hand the creationist movement and its religious arguments against Darwinian evolution have become increasingly visible to the public since the 1980s, especially in the English-speaking world, and offer clear evidence of the potential for conflict between Protestantism and science. Finally, as I will elaborate in the next section, a number of recent studies focused on science in Catholic contexts in early modern Europe undermine the initial quantitative assumptions of Protestant superiority that drove the claims of de Candolle and Merton.[xxxiii]

Even if we set aside many of the earlier arguments about "Protestantism and science" and their frequently confessional motivations, it is reasonable to consider under this heading the considerable body of research on specific cases of the interaction between religion and science in Protestant contexts. Protestantism took different forms in different contexts and its lack of unity and of a central religious authority is one of its defining characteristics. Protestantism involved no particular predisposition toward scientific innovation. Luther and Calvin are noted for their general lack of interest in the study of nature.[xxxiv] But pedagogical demands in both confessions

led to the institutionalization of the teaching of natural philosophy. By the 1550s in Strasbourg and the 1570s in Geneva Hieronymus Zanchi and Lambert Daneau respectively taught natural philosophy and published textbooks with a stated preference for the authority of the Bible over philosophers and yet an emphasis on finding agreement between the Bible and Aristotle.[xxxv] In building the model curriculum for use in Lutheran institutions Melanchthon gave an important place to natural philosophy which would show the providence of God in the natural world.[xxxvi] Melanchthon had a particular interest in astronomy, notably as an aid to astrology; his presence at Wittenberg was no doubt instrumental in fostering interest there in Copernicus.[xxxvii] Wittenberg was the site of the first group of astronomers to master Copernicus' system and use it to draw up new astronomical tables, the Prutenic tables of 1551. The "Wittenberg interpretation" of Copernicus, centered around Erasmus Reinhold, was a fictionalist one which used Copernicus' theory for computational purposes but denied that heliocentrism was a real physical phenomenon.[xxxviii]

One of the earliest convinced Copernicans, Johannes Kepler, was a Lutheran too, trained at Tübingen, where Melancthon had established the curriculum.[xxxix] Kepler's deeply religious motivations in seeking the mathematical harmonies underlying the distribution, size and distances of the planets are well known. He first explained the arrangement of the planets by a series of perfect Platonic solids in the Mysterium cosmographicum (1596). But Kepler's own exacting empirical standards led him to question his use of the planetary data, notably in detailed footnotes in a later edition of the Mysterium, and ultimately to reject this scheme in favor of another one, based on musical harmonies, in his Harmonices mundi (1619), which also contained in passing the mathematical relationships later known as "Kepler's laws" of planetary motion.[xl] Kepler labored intensively with the observational data gathered by Tycho Brahe, driven by the

conviction that God must have created the heavenly planets and their motions according to a beautiful mathematical plan. A devout and orthodox Lutheran, Kepler even tried to identify the logic of the Trinity in some triadic features of the heavens, without showing any concern for specific Biblical passages which seemed to contradict heliocentrism.[xli]

Scriptural objections certainly did play a role in the rejection of Copernicanism by other Lutherans, such as Tycho Brahe himself, who prided himself on offering a geo-heliocentric cosmology which offered the advantages of Copernicanism without its signal disadvantages of flying in the face of all known physics and of the straightforward interpretation of various biblical passages.[xlii] Protestant opposition to Copernicanism continued to surface down to the late 17th century when conservative Dutch Calvinists invoked scriptural objections to reject Copernicanism and the Cartesianism with which it had become associated; these intellectual positions were often driven by the politics of power struggles within Church and state and resulted in the condemnation of Cartesianism by the theology faculty of Leiden in 1659.[xliii] Protestant exegetical principles allowed for a broad range of interpretations of problematic passages like Joshua 10:12 and, unlike Catholic principles, did not require adherence to an interpretation because it was traditional. While some Protestants favored literalism, on the grounds, given for example by the conservative Calvinist Gisbert Voetius, that it was invidious to imply that the Holy Ghost either could not or would not speak the truth in the Bible, many explained the passage as accommodated to the understanding of its Hebrew audience. In addition to Calvin's own use of the principle of accommodation, Galileo's arguments concerning Copernicanism were available in a Latin translation of his "Letter to the Grand Duchess Christina" published in 1636. Other explanations advanced by Calvinists included Grotius' suggestion (following Jewish exegesis) that the passage was a poetic exaggeration or the claim

that the standstill of the sun was an optical illusion.

Given that some Catholics too favored heliocentrism before and even after and despite the condemnation of Galileo in 1633, cosmological positions cannot be correlated with particular religious affiliations. The deep religious commitments characteristic of early modern thinkers led individuals in each confession to different positions on Copernicanism depending in part on their preferences in admiring God for the beauties of mathematical order and rational simplicity or rather for a more mysteriously complex natural order supported by literal and traditional readings of the Bible.

Seventeenth-century England, which served as the principal evidence for a special relationship between Protestantism and science, continues to offer a rich field of investigation. A wide range of scientific activity, from the utilitarian pursuits of "mathematical practitioners" to the experimentation at the Royal Society designed to elucidate aspects of the mechanical philosophy, can be attributed to a vision of the benefits of science that was most famously articulated by Francis Bacon (1561-1626). In his unfinished Instauratio magna Francis Bacon envisioned a plan for moral and philosophical reform which would restore Adam's lost dominion over nature; Bacon distinguished ethical mastery which had been denied the human race after the Fall, from natural and technical mastery which had never been forbidden--indeed it was a divine injunction which had never fulfilled. Bacon outlined a method for collective scientific endeavor which would reach reliable generalizations about nature by confronting a plethora of individual facts or "instances" gathered from observation and purposeful experimentation.[xliv] Though Bacon never completed any such investigation himself nor managed to secure the royal funding for his project that he had hoped, his methodological manifesto proved a powerful inspiration for generations to come, particularly but not exclusively in England. Bacon was careful to warn

against an intermingling of science with theology, although his utopian vision in New Atlantis depicts the ranks of scientific workers on the model of an ecclesiastical hierarchy. Bacon's various followers agreed with him on the close link between moral and philosophical reform, but conceived of it in different ways.[xlv]

One group inspired by Bacon's vision, the Office of Address formed around the Polish-born Calvinist Samuel Hartlib, harbored radical visions for social and religious reform, often millenarian in tone, and in natural philosophy focused on Paracelsianism, astrology and the pansophy of Comenius; after flourishing during the Interregnum, they were marginalized and dispersed under the Restoration. In 1662 the members of two other informal groups (the "1645 group" in Oxford and the "Invisible College" around Robert Boyle) requested approval from the king to form the Royal Society in 1662. The Royal Society included a large and dispersed membership but was run by a core of some twenty active London members who focused on making natural philosophy safe from political and religious controversies and the potential for royal disfavor.[xlvi] They specialized in reporting on "matters of fact"--accounts of observations and experiments-- about which they hoped there would be no disagreement.[xlvii] The members of the Royal Society embraced a mechanical philosophy adapted from Descartes, which interpreted all natural phenomena as the motions of inert particles of matter. True to Bacon's vision they presented their experimental mechanical philosophy as the bulwark of good Christian piety. Their demonstrations of the workings of divine providence throughout nature were offered as an antidote against atheism, which was perceived as an ever-increasing threat. Their sober research into facts was an antidote against religious enthusiasm, with its hasty "imaginings" (e.g. about supernatural interventions) and the risk of dangerous social disturbances.[xlviii]

The English experimentalists dwelt at length on the intricate beauty of the organic world,

as examined for example under microscope in Hooke's Micrographia of 1665, and the mathematical regularities of the planets, as magisterially demonstrated in Newton's Principia of 1687. "Physico-theology" came to be used to describe the many works of physics or natural philosophy couched as demonstrations of divine providence, power and benevolence in nature.[xlix] Some formulations of natural theology emphasized the rationalization of divine actions to such an extent that revelation could seem to serve only as a confirmation of truths derived from natural religion.[l] Others, like Robert Boyle, emphasized the greatness of God by insisting on the limits of human reason.[li] The lecture series which Boyle endowed at his death in 1691 would perpetuate his project of proving Christianity against infidels and atheists without engaging in internecine doctrinal disputes--natural theology was a favorite theme of Boyle lecturers for decades to come. Recent studies of the oeuvre of Isaac Newton, from his famous mathematical works to his abundant theological and alchemical manuscripts, have emphasized his deeply religious motivations.[lii] In establishing the laws of physics Newton was striving to uncover the workings of God throughout nature and history; these included not only regular laws but also occasional direct interventions, required for example to insure the continuity of the planetary motions, and miraculous moments in history. But Newton kept his religious views private and for good reason, since they were anti-trinitarian--an unorthodoxy that could not have been officially tolerated at the time.[liii]

Seventeenth-century England proved fertile ground for the development of experimental mechanical philsophy and natural theology. Restoration England was tolerant of a range of Protestant beliefs, from high Church Anglicanism to Puritanism, though not including Catholics, dissenters or Arians. A Puritan like Samuel Hartlib, a conservative Anglican like Robert Boyle, an Arian who concealed his views (like Isaac Newton) and one who tended toward natural

religion (like John Locke) could each bring their religious commitments to their philosophical work and feel that they were participating in one broadly Baconian project of reforming society through the study of nature. Natural theology proved such a successful framework precisely because it too encompassed a wide range of motivations, from the rationalistic to the more purely religious. Seventeenth-century England offers a fine example of the harmonious cooperation between science and religion, and yet it also put in place structures of thought that would later prove problematic for the relationship. Natural theology proposed scientific grounds on which to rest religious faith, based on assumptions about an act of Creation which proved divine power, wisdom and providence. When this assumption was challenged by Darwin's notion of evolution by natural selection, science and religion suddenly seemed irreconcilable enemies to many in the late nineteenth century and since. For over two hundred years English natural theology had been so successful in its broad appeal that it masked tensions generated by complex changes in the status of theology and of the natural sciences, which had become increasingly independent and professionalized, and between various strands within Protestantism; when these tensions burst into the open under the impact of Darwin, the metaphor of a warfare between science and religion became predominant.

Catholic Science

Although Draper and White, both Protestants, were delighted to point to Catholicism as the first source of the conflict between science and religion, there was no indication of such a conflict prior to the Galileo Affair. In many ways the Catholic Church and its medieval antecedent offered a favorable context for the development of natural philosophy--though not, as Duhem had argued, through the condemnations of 1277. Those early condemnations had been

meant to thwart the entry of Aristotle into the university curriculum and might well have done so, had they not been undercut by the success of the skillful Christianization of Aristotle offered by Thomas Aquinas. Instead the Church fostered the development of science by adopting many features of Aristotelian methodology and in posing questions about nature in the teaching of theology itself, spurring debate and discussion on, among other questions, the intension and remission of forms or the qualities of motion.[liv] Furthermore the Church offered opportunities for education and life-long careers to secular and regular clergy which often gave them the freedom to pursue scientific interests. Finally, the institutional separation between the theology and the arts and medical faculties left philosophy and medicine often free from explicit theological regulations. As noted above, the Church showed an interest at the Lateran Council in harnessing philosophy to serve the needs of theology, by demonstrating the immortality of the soul. But aside from the condemnation Pomponazzi and the condemnation and arrest of Pico della Mirandola (1488), which were resolved by the publication of apologies, the Church had intervened little in philosophy before the Counter-Reformation.

In response to the threat of Protestantism the Church issued the first Index of forbidden books in 1559; early indexes included all works by heretics, including works of science, but later versions were moderated, so that, for example, the natural histories by Protestants like Gesner and Fuchs could be read after emendation.[lv] Scientific works were often published, distributed and read across the Protestant-Catholic divide in both directions. More damaging were the decrees of the Council of Trent concerning biblical interpretation, which were designed to ensure that the Catholic church would remain united against Protestantism: the Catholic laity was not allowed to interpret the Bible; Catholic interpretation must respect the traditional interpretations of the Church fathers and doctors. These principles were the result of theological conflicts with

Protestantism and were not directed at nor motivated by issues in natural philosophy, but they came to have a large impact on astronomy and natural philosophy through the condemnation of Galileo.

The historiography on the Galileo Affair is vast and ranges from interpretations which lay the blame solely on the Counter-Reformation Church to those which hold Galileo and his acerbic personality responsible. The historiography has examined the complex politics of church factions (Jesuits and Dominicans) and philosophical ones (Galileo's disputes with Scheiner, Grassi and the Aristotelian "pigeonists" around Ludovico delle Colombe) and the role of individual personalities, including Urban VIII (who felt his trust in Galileo had been betrayed), Robert Bellarmine (who had a special interest in natural philosophy) and Galileo, with his ambitions for a career at the Medici court.[lvi] The Galileo Affair involved a tangled web of causes, many of them contingent. But it also resulted from a deep intellectual conflict over the control of biblical interpretation and the kind of scientific evidence that the Counter-Reformation Church required to justify relinquishing a traditional interpretation of the Bible. These tensions were bound to play themselves out at some point on the issue of the motion of the earth, and the timing of Galileo's Dialogue concerning the two chief world systems (1632) precipitated a conflictual outcome. Copernicanism did not yet have the support of a large number of astronomers nor of a physics that explained it (like Newton's)--Galileo's Dialogue helped to foster both-- and the Counter-Reformation Church was inclined to enforce rigidly the interpretive principles laid out at Trent.[lvii]

Even before Trent Nicolaus Copernicus had been fearful of the reception of his heliocentric theory by the Catholic Church in which he served as a cathedral canon (in Frombork, Poland). Copernicus delayed publication of his work until the year of his death and

offered it to Pope Paul II as a contribution to the Church's project of calendar reform; he also included a letter of support from bishop Schönberg. Unbeknownst to Copernicus the Lutheran Andreas Osiander, probably at the behest of the printer, tried to facilitate the reception of the work by explaining, against Copernicus' own realist claim, that the heliocentric hypothesis was not a description of reality but only an elegant computational device. As it happened, and perhaps thanks to these preventive measures, the publication of De revolutionibus elicited no ecclesiastical reaction from either Catholics or Protestants. It was a difficult, technical work which few were able to or interested in reading. Two early Catholic responses attest to the breadth of possible responses: a pre-tridentine manuscript by the Dominican Tolosani was critical, while in 1584 the Spanish Augustinian Diego de Zuniga published a favorable assessment of heliocentrism and an interpretation of the some of the problematic biblical passages. But Zuniga's interpretations were condemned in 1616.[lviii]

Galileo prudently never published his own arguments for biblical interpretations to allow for or even support the motion of the earth. But Bellarmine was aware of the arguments of Galileo's "Letter to the Grand Duchess Christina" which circulated in manuscript in 1615. Galileo adduced the authority of Augustine to argue that passages which seemed to indicate that the earth was stationary were accommodated to the understanding of the Hebrews and should be reinterpreted in light of evidence for the motion of the earth.[lix] Bellarmine on the contrary maintained that though the Church Fathers had not addressed the question of the motion of the earth, their traditional interpretations were binding until and unless demonstrative proof was made of the motion of the earth--a proof that Bellarmine was convinced would be impossible. The condemnation of heliocentrism in 1616 as "foolish and absurd in philosophy and formally heretical since it explicitly contradicts in many places the sense of Holy Scripture", made no

mention of Galileo.[lx] It was precipitated by the imprudent publication of new biblical interpretations in support of Copernicanism by the Carmelite priest Paolo Antonio Foscarini. Some fifteen years later, after friendly conversations with Urban VIII and armed with a written certificate that cleared him of any suspicion of wrongdoing, Galileo was confident that he had demonstrative proof of Copernicanism and was authorized to publish a discussion of Copernicanism as a hypothesis. In the Dialogue Galileo did indeed devote the final page to a confession of ignorance on the question of cosmology, but only after writing hundreds of pages mocking Aristotelian objections to the motion of the earth and attempting to prove heliocentrism from the motion of the tides. In 1633 Galileo was charged with disobeying both the decree of 1616 and an unsigned injunction which summoned him in particular to cease teaching Copernicanism, which was found in the files of the Inquisition, unbeknownst to Galileo. Galileo was found guilty of "strong suspicion of heresy" and condemned to house arrest. He died in 1642, after composing in his last years a treatise on the physics of motion.

The condemnation of Galileo had a lasting impact on what cosmology Catholics could teach and defend. Catholics were forbidden to support heliocentrism publicly until 1833 when Copernicus was finally taken off the Index.[lxi] For early modern Catholics the solution of choice to the cosmological question was to adopt the observationally equivalent Tychonic geoheliocentric system, in which all the planets except the earth revolved around the sun, which in turn revolved around a stationary earth. Better yet, as Newton sealed the acceptance of heliocentrism in 1687, Catholics most often opted to engage in other kinds of scientific work. The Jesuits were noted for producing fine astronomers in the 17th century, who devoted their efforts to observations and avoided cosmology altogether.[lxii] The Jesuits had long been particularly active in mathematical sciences, following the efforts of Christopher Clavius to

elevate the status of mixed mathematical disciplines and they continued to be at the forefront of teaching and research in many mathematical disciplines.[lxiii] The buildings of many a Catholic church were used as instruments of astronomical measurement.[lxiv] Despite his public humiliation, Galileo himself fostered a school of followers in Italy who worked on the physics of motion, not cosmology.[lxv] Francesco Redi (1626-98) and Marcello Malpighi (1628-94) carried on the tradition of anatomical and medical research which played an essential role in William Harvey's work on the circulation of the blood (De motu cordis, 1628).[lxvi]

Outside Italy the Church fostered the careers of innovatirve natural philosophers like the Minim Marin Mersenne and the Oratorian Gassendi. Blaise Pascal did his work in physics (e.g. on barometric pressure) before his conversion to a more austere religious outlook and Jansenism (to the which the Church was consistently hostile). René Descartes, who was condemned by both Protestants and Catholic institutions for the potentially irreligious consequences of mechanical philosophy, thought of himself as a devout Catholic; indeed his motivation to develop a new philosophy is attributed to a conversation with the Counter-Reformation cardinal Bérulle.[lxvii] Descartes sent copies of his work to the Jesuits at La Flèche where he was educated, evidently in the hope that they would adopt his ideas in the curriculum. Descartes was careful to remain a Catholic in good standing; he explicitly alluded to the condemnation of Galileo in explaining why he did not publish his cosmological system, Le monde. But the spread of Cartesianism played a major role in diffusing Copernicanism; after initial resistance and condemnation, even the Unviersity of Paris adopted Cartesianism for its curriculum in 1690s. There is no identifiably Catholic character to the variety of scientific pursuits and results achieved by early modern Catholics--they did not even agree on rejecting Copernicanism as the Church had decreed.

Coda:

In keeping with the dominant orientation of the historiography on science and religion, this brief survey has focused mostly on the impact of religion on science, as studied especially by historians of science. It would take another kind of expertise to disentangle the role of science from among the many forces shaping changes in religion in the early modern period, but the new confidence in scientific explanation was no doubt an important factor driving the rationalization of religion and the development of natural religion in the late 17th century.

NOTES

I am grateful for helpful comments to Anthony Grafton and Mordechai Feingold and the editor of the volume.

---

i I will use the term "science" for convenience, as historians of science often do, to designate the various forms that the study of nature took in early modern Europe, which are often quite different from the practices and assumptions we associate with modern science. Since the term is anachronistic, I will also use terms that correspond better to the categories of the historical actors, such as natural philosophy, natural history, astronomy, mathematics and medicine.

ii See Daston and Park (eds.), Cambridge History of Early Modern Science, including an article on "Religion" by Rivka Feldhay.

iii For a rich array of recent case studies, see Helm and Winkelmann (eds.), Religious Confessions and the Sciences, Fatio (ed.), Les églises face aux sciences and Sciences et religions de Copernic à Galilée.

iv See Grant ed., A Source Book in Medieval Science, 45-50. For the debates surrounding these theses, see Thijssen, "What Really Happened on 7 March 1277?"

v On this theme see Courtenay, Capacity and Volition.

vi See Pine, Pietro Pomponazzi.

vii Kraye, "The Philosophy of the Italian Renaissance", 42.

viii Mercer, "The Vitality and Importance of Early Modern Aristotelianism", p. 47.

ix See Menn, "The Intellectual Setting".

x Hankins, "Marsilio Ficino as a Critic of Scholasticism".

xi For detailed bibliographical references on these and other figures, see my contribution on "Natural philosophy", in Daston and Parks (eds.), Cambridge History of Early Modern Science.

xii Firpo, "The Flowering and withering of speculative philosophy", 278.

xiii Osler, "Baptizing Epicurean atomism".

xiv Barker, "Stoic Contributions to Early Modern Science".

xv On these and other anti-Aristotelian philosophers, see Kristeller, Eight Philosophers of the Italian Renaissance.

xvi Gunnoe, "Parcelsus's Biography Among his Detractors". Paracelsus never left the Catholic Church nor faced any persecution, but expressed a spiritualist and anti-clerical conception of religion in works he left in manuscript.

xvii See Gilly, "'Theophrastia Sancta'", 166.

xviii See Hotson, Paradise Postponed.

xix Blair, "Mosaic Physics".

xx On the confession of ignorance, see Blair, The Theater of Nature, 92-93, 144-46.

xxi Aristotelianism in the schools often acquired new eclectic features, incorporating elements from outside the Aristotelian tradition; for more on this eclecticism see Schmitt, Aristotle and the Renaissance.

xxii See Ariew, "Descartes and Scholasticism", 64-65.

xxiii On the brief attempt by Melanchthon to teach natural philosophy from Pliny instead of Aristotle, see Kusukawa, The Transformation of Natural Philosophy, 175.

xxiv Frans Titelmans, Compendium naturalis philosophiae (Paris: Michael de Roigny, 1582; first published 1542). See Schmitt, "The Rise of the Philosophical Textbook".
xxv Philip Melanchthon, Doctrinae physicae elementa (Lyon: Jean de Tournes and Gul. Gazeius, 1552).
xxvi For an introduction to the vexed question of the existence of atheists in this period, see Hunter and Wootton (eds.), Atheism from the Reformation to the Enlightenment.
xxvii See Cunningham, "How the Principia Got its Name".
xxviii See Feldhay and Heyd, "The Discourse of Pious Science".
xxix For example, a special impetus for natural theology has been attributed to the Lutheran doctrine of real presence in Barker, "The Role of Religion in the Lutheran response to Copernicus", 61, or to the Calvinist sense of obligation to study God's creation in Knoeff, Herman Boerhaave (1668-1738), 10. But Catholic natural theology also thrived in the multi-volume Spectacle de la nature by the Abbé Antoine Pluche which was among the most widely owned books in mid-18th century Parisian private libraries; see Mornet, "Les enseignements des bibliothèques privées (1750-1780)", 460.
xxx On Duhem see Wallace, "The Philosophical Setting of Medieval Science", 105-6. Alphonse de Candolle first published this claim in Histoire des sciences et des savants depuis deux siècles (1873).
xxxi For a convenient sampling of the debate, see Cohen (ed.), Puritanism and the Rise of Modern Science.
xxxii For a classic set of such arguments, see Hooykaas, "Science and Reformation", and Religion and the Rise of Modern Science.
xxxiii This point was already made by Russo, "Le rôle respectif du catholicisme et du protestantisme".
xxxiv Kusukawa, The Transformation of Natural Philosophy, 188-89, 205. For more detailed discussion see Gamble, Calvin and science.
xxxv On Zanchi see Harrison, The Bible, Protestantism and the Rise of Natural Science, 138; and Donnelly, "Calvinist Thomism".
xxxvi Kusukawa, The Transformation of Natural Philosophy, 187. For a study of Melanchthon's manuscript "Physicae seu naturalis philosophiae compendium" (1543), see Bellucci, Science de la nature et Réformation.
xxxvii Barker, "The Role of Religion", 65-68.
xxxviii Westman, "The Melanchthon Circle". For further research on this topic, see Westman and Gingerich, The Wittich Connection and Gingerich, An annotated census of Copernicus' De revolutionibus.
xxxix Methuen, Kepler's Tübingen.
xl See Johannes Kepler, Secret of the Universe tr. A. M. Duncan (New York: Abaris Books, 1981); Field, Kepler's Geometrical Cosmology and Stephenson, The Music of the Heavens.
xli Westfall, "The Rise of Science and the Decline of Orthodox Christianity", 222-24.
xlii Blair, "Tycho Brahe's Critique of Copernicus".
xliii Vermij, The Calvinist Copernicans, 239-31, 309-13; for the interpretations by Voetius and Grotius which follow, see 249-51 and 243-46.
xliv For an introduction to Bacon see Peltonen (ed.), Cambridge Companion to Bacon.
xlv For a detailed account of Bacon's legacy see Webster, The Great Instauration; also Gieryn, "Distancing Science from Religion".
xlvi Hunter, The Royal Society and Its Fellows.

xlvii Shapin, A Social History of Truth, 308-9.
xlviii See Joseph Glanvill, Philosophia pia or a discourse of the rel temper and tendencies of the experimental philosophy of the Royal Society (1671), as discussed in Westfall, Science and Religion in Seventeenth-Century England, 130.
xlix Major examples include John Ray, The Wisdom of God manifested in the works of Creation (1691) and William Derham, Physico-theology (1713).
l For example in the case of John Locke who moved close to a rational religion in The Reasonableness of Christianity (1695). For a short survey of this movement see Lagrée, La religion naturelle.
li See Wojcik, Robert Boyle and the Limits of Reason; Sargent, The Diffident Naturalist.
lii See for example Dobbs, "Newton as Final Cause and First Mover".
liii See Westfall, "The Rise of Science", pp. 228-34. More generally, Cohen and Westfall (eds.), Newton.
liv See Edward Grant, "Science and Theology in the Middle Ages", in Lindberg and Numbers (eds.), God and Nature, 49-75.
lv See Fragnito (ed.), Church, Censorship and Culture in Early Modern Italy.
lvi For a brief account of the Affair, see William Shea, "Galileo and the Church", in Lindberg and Numbers (eds.), God and Nature, 114-35.
lvii There is no evidence to support the claim that Galileo was condemned for atomist views rather than heliocentrism, as advanced in Redondi, Galileo Heretic. See, among other refutations, Ferrone and Firpo, "From Inquisitors to Microhistorians". Redondi nonetheless offers a compelling portrait of many of the people and places involved in the Galileo Affair.
lviii For more detailed treatment of the material I survey here, along with related primary texts, see Blackwell, Galileo, Bellarmine and the Bible.
lix "Accommodation" refers to the message of the Bible being accommodated to its audience, not to philosophy being reconciled with religion, although the principle of accommodation was often useful in achieving that end.
lx See Finocchiaro (ed.), The Galileo Affair, 146.
lxi On the attempt to remove Copernicus from the Index in 1757, Mayaud, La condamnation des livres coperniciens.
lxii See Feingold (ed.), The New Science and Jesuit Science.
lxiii On Clavius see Lattis, Between Copernicus and Galileo; for recent work on the Jesuit polymath Athanasius Kircher, see Findlen (ed.), Athanasius Kircher.
lxiv Heilbron, The Sun in the Church.
lxv Segre, In the Wake of Galileo.
lxvi See Bertoloni Meli, "Francesco Redi e Marcello Malpighi".
lxvii On the condemnation of Descartes, see Jolley, "The Reception of Descartes' Philosophy". Baillet, Vie de Monsieur Descartes, I, 160-65.