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The Rise of Modern Science and the Decline of Theology as the 'Queen of Sciences' in the Early Modern Era

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Abstract

The early modern period witnessed an important transformation in the Christian tradition of determining who had the authority to speak for nature and to read the Deity's mind in nature. This profound change was inextricable from the rise of modern science. This essay will argue that the development of modern scientific reasoning was preconditioned largely by the dethroning of theology from its status as the queen of sciences, with reference to the works of Nicolas Copernicus, Johannes Kepler, and Galileo Galilei. Impelled by the growing discrepancy between their new astronomical discoveries and traditional scholastic philosophical thought, they developed new conceptions and re-defined their relation to theology. To establish the science of astronomy on new foundations, they argued that Scripture was not intended to describe the phenomena of the world; hence theology had no business assessing the merit of astronomical arguments. These pioneers refused to accord any priority to theology in explaining and interpreting the phenomena of astronomy. They asserted that astronomy was not a 'handmaiden to theology' rather an authoritative means of speaking for nature. They all admitted that in relation to divine things, theology was indeed superior to all other sciences in explaining human salvation and redemption. On natural phenomena, however, its conventional role was no longer secure in the face of astronomical discoveries. Theology concerns transcendent issues, science mundane ones; the first deals with salvation and the second with the workings of nature.

Who could speak for nature? Who has the authority to unveil its secrets? And who, eventually, has the legitimacy to interpret it? Until the early modern period the answer to these questions was clear—theology. Since the Bible was assumed to be the oracle of God, a book in which the Holy Ghost revealed the Deity's intention in, and knowledge of creation, priority was ultimately given to theological dimensions in explaining natural phenomena. It was accepted that 'God' had authored two 'books,' Scripture and Nature (*libri naturales*); hence his voice as revealed in both should be interpreted by the Church, speaking through its clergy and theologians. During the Middle Ages, therefore, theology was accorded the title of the 'Queen of Sciences' (*Regina scientiarum*), and 'natural philosophy,' or science, was defined as 'handmaiden to theology' (*philosophia ancilla theologiae*). The view continued to be represented by Christian Renaissance Humanism figures like Erasmus, who remarked that 'Theology is rightly the queen of sciences.'[1]

The early modern period, however, witnessed an important transformation in the long established Christian tradition concerning who could speak for nature and who was entrusted to read the Deity's mind in nature, and this profound change was inextricable from the rise of modern science. In his essay, 'What is Enlightenment?' (1784), Immanuel Kant (1724–1804) wrote: '*Enlightenment is mankind's exit from its self-incurred immaturity. Immaturity* is the inability to make use of one's own understanding without the guidance of another.'[2] In the same vein of argument one can say that modern scientific thought emerged with its release from the traditional tutelage to theology. Or, conversely, in the broad course of the history of ideas, the development of modern scientific reasoning was preconditioned to a large extent on the dethroning of theology from its place as the queen of sciences. This is how Immanuel Kant defined this important transformation:

> There was time when metaphysics was called the 'queen' of all the sciences, and if the will be taken for the deed, it deserved this title of honor, on account of the preeminent importance of its subject. Now, in accordance with the fashion of the age, the queen proves despised on all side; and the matron, outcast and forsaken, mourns like Hecuba: '*Greatest of all by race and birth, I now am cast out, powerless*' (Ovid, *Metamorphoses*, 13:508–510)[3]

1. *Adagia* IV, V, 1, in *Desiderii Erasmi Roterodami opera omnia,* ed. Jean Leclerc (Leiden, 1703–1706), vol. 2, 1053F.
2. Immanuel Kant, 'What is Enlightenment?' in *What is Enlightenment? Eighteenth-Century Answers and Twentieth-Century Questions*, ed. James Schmidt (Berkeley: University of California Press, 1996), 58. Emphasis in original.
3. Immanuel Kant, *Critique of Pure Reason*, trans. P. Guyer and A.W. Wood (Cam-

During the sixteenth and seventeenth centuries a new contender appeared who claimed to have authority and legitimacy to speak for nature–science. This can be seen in the works of three forerunners of modern scientific thought —Nicolas Copernicus (1473–1543), Johannes Kepler (1571–1630), and Galileo Galilei (1564–1642). Impelled by the growing discrepancy between their new astronomical discoveries and traditional scholastic philosophical thought, they developed new scientific conceptions and re-defined their relation to theology. More specifically, to establish the science of astronomy on new foundations, they argued that Scripture was not intended to describe the phenomena of the world; hence theology had no business assessing the merit of astronomical arguments, such as Copernicus's heliocentric system. These pioneers of modern science refused to accord any priority to theological considerations in explaining and interpreting the phenomena of astronomy. They asserted that the science of astronomy should not be construed as a 'handmaiden to theology' but rather as possessing authority to speak for nature. They all admitted that as far as divine things were concerned, theology was indeed superior to all other sciences in explaining human salvation and redemption, yet as regards natural phenomena, its traditional role was no longer secure in the face of astronomical discoveries. Theology concerns transcendent issues, science mundane ones, the first deals with salvation and the second with the explanation of nature.

This rise of science was greatly intertwined with Renaissance philosophy and the Protestant Reformation. Renaissance philosophy referred to the 'philosophical activity within the area in which Latin was used as a cultural language from the age of Ockham to the revisionary work of Bacon, Descartes and their contemporaries.'[4] One of its hallmarks was 'an accelerated and enlarged interest, stimulated by newly available texts, in primary sources of Greek and Roman thought that were previously unknown or partially known or little read.'[5] Along with this restoration of learning and scholarship, to that age belong the invention of printing, the discovery of the New World, the Protestant and Catholic Reformations, and the 'new' philosophy of nature, or the rise of modern science. The new astronomy of Copernicus, Kepler and Galileo was part of Renaissance philosophy, which 'saw a

bridge: Cambridge University Press, 1998), 99.

4. Charles B. Schmitt and Quentin Skinner, 'Introduction,' in *The Cambridge History of Renaissance Philosophy*, eds. Charles B. Schmitt and Quentin Skinner (Cambridge: Cambridge University Press, 1988), 5.
5. Brian P. Copenhaver and Charles B. Schmitt, *Renaissance Philosophy* (Oxford: Oxford University Press, 1992), 4.

number of "new" philosophies— "new" in the sense of "non-Aristotelian"' that 'challenged scholastics' and 'Christian orthodoxy.'[6] The goal of Renaissance philosophers—such as Nicholas of Cusa (1401–1464), the 'first "new philosophers" of the Renaissance,' Marsiglio Ficino (1433–1499), Pico della Mirandola (1463–1494), and others—was to transform scholastic traditions inherited from the Middle Ages and to assume power over nature. This was an important characteristic of the Renaissance as a whole and a precondition for the emergence of the new science in the early modern period in particular. For example, the new experimental technique of alchemy—the 'black art'—that arose in the late Renaissance was based on the view that 'God was manifested not only in the heavens but also in the whole of the earthly reality.' Hence 'it was possible to discover the divine within the material.'[7] No wonder that 'theologians' accused the 'new philosophies' of 'wanting to make philosophy the rival rather than the handmaid to theology.'[8]

The Protestant Reformation also contributed to the rise of science with its concept of God's radical sovereignty, or the view that 'God's sovereignty excluded the active contribution of lesser beings to his work.' During the Middle Ages, Thomas Aquinas (1224–1274) produced a majestic synthesis of Aristotelian natural philosophy and Christian theology by interpreting 'Aristotle's principles inherent in nature as powers instilled there by God, which God used in his providential work.' Accordingly, 'God *cooperated* with natural powers in a way that respected their integrity while accomplishing his purposes.' Unlike this medieval theory of cooperation, and against the Graeco-Roman *Deus sive natura* world-view (as formulated by Spinoza), 'the Reformation believed that an adequate understanding of sovereignty necessitated the exclusion of any contribution to divine providence from human beings or nature.' To protect therefore the glory of God and avoiding making the God's actions contingent on the actions of created being, 'the reformers affirmed the concept of radical sovereignty against the medieval view of accommodating sovereignty, or cooperation.'[9] This was essential to the development of experimental science: 'the world had to become *demytholo-*

6. James Hankins, 'Introduction,' in *The Cambridge Companion to Renaissance Philosophy*, ed. James Hankins (Cambridge: Cambridge University Press, 2007), 5.
7. Harold P. Nebelsick, *The Renaissance, The Reformation and the Rise of Science* (Edinburgh: T&T Clark, 1992), 134.
8. Hankins, 'Introduction,' 6.
9. Gary B. Deason, 'Reformation theology and the Mechanistic Conception of Nature,' in *God & Nature: Historical Essays on the Encounter between Christianity and Science*, eds. David C. Lindberg and Ronald L. Numbers (Berkeley: University of California Press, 1986), 169–170.

gized or *disenchanted* of its "immanent divinity."' Reformed thought thus deprived nature of intrinsic powers and purposes apart from the hand of God, and consequently 'tamed nature for [scientific] investigation.'[10]

Regina Scientiarum—Theology as the 'Queen of Sciences'

As stated, in the medieval scholastic world, theology was defined as the 'Queen of Sciences' and science as 'handmaiden to theology.' The natural sciences and philosophy were thus assigned a subordinate and servile role. They had the privilege of being employed in the defence of revealed truths, providing support and aid in achieving soteriological understanding. The revealed, undemonstrated truths of faith thus had priority over demonstrated truths of reason. In Christian theology revelation is superior to all forms of knowledge, since in the study of salvation—soteriology—redemption is primarily through Christ, faith and grace, and not through reason. The rise of modern science during the sixteenth and seventeenth centuries to a large extent signified rejection of this traditional scholastic view by exalting reason in approaching world phenomena. In his 'Ode Dedicated to Isaac Newton' (1687), Newton's friend, the astronomer Edmund Halley (1656–1742), wrote: 'In reason's light, the cloud of ignorance / Dispelled at last by science.'[11] Roger Cotes (1682–1716), Fellow of Trinity College Cambridge and Plumian Professor of Astronomy and Experimental Philosophy, wrote in his 'Preface' to the second edition of Newton's *Principia* in 1713 that instead of theological causation 'this most excellent method of philosophy,' namely experimental, mechanical philosophy 'is founded on experiments and observations.'[12]

The 'handmaiden view' is originated with Augustine, who 'accepted Greek philosophy as a useful, if not perfectly reliable, instrument. Philosophy, in Augustine's influential view, was to be the handmaiden of religion—not to be stamped out, but to be cultivated, disciplined, and put to use.'[13]

> If those who are called philosophers, particularly the Platonists, have said anything which is true and consistent with our faith, we must not reject it,

10. Nebelsick, *The Renaissance, The Reformation and the Rise of Science*, 149, xix.
11. Edmund Halley, 'Ode Dedicated to Newton', in *Sir Isaac Newton's Mathematical Principles of Natural Philosophy and His System of the World*, ed. Florian Cajori, 2 vols. (Berkeley: University of California Press, 1934), I, xiv.
12. Roger Cotes, 'Cotes's Preface to the Second Edition,' in *Sir Isaac Newton's Mathematical Principles of Natural Philosophy and His System of the World*, I, xxxii.
13. David C. Lindberg, *The Beginnings of Western Science: The European Scientific Tradition in the Philosophical, Religious, and Institutional Context, 600 B.C. to A.D. 1450* (Chicago: University of Chicago Press, 1992), 150.

> but claim it for our own use, in the knowledge that they possess it unlawfully … pagan learning is not entirely made up of false teachings and superstitions. It contains also some excellent teachings, well suited to be used by truth, and excellent moral values. Indeed, some truths are even found among them which related to the worship of one God … The Christian, therefore, can separate these truths from their unfortunate associations, take them away, and put them to their proper use for the proclamation of the Gospel.[14]

Indeed, Augustine did not doubt the utility of pagan philosophy, particularly the liberal arts, for Christians: 'all the teachings of the pagans contain' not only 'superstitious imaginings' but also 'liberal disciplines more suited to the uses of the truth, and some most useful precepts concerning morals.'[15]

Augustine's views became the staple of medieval theology. The Seraphic Doctor, St. Bonaventure (1221–1274), argued that 'theology is the queen of the sciences, because in the final analysis, all learning and knowledge depend upon divine illumination from sacred Scripture, the study of which is the exclusive domain of theologians.' In Bonaventure's thought, as with many scholars of the thirteenth century, 'faith and reason were harmoniously unified, with the former ultimately guiding and informing the latter.'[16] For Roger Bacon (1214–1294), using Augustine's handmaiden formula, '*scientia* as a whole was the handmaiden of theology.'[17] In his *Opus maius* (1267), the *Doctor Mirabilis* argued that there is

> one perfect wisdom, and this is contained in holy Scripture, in which all truth is rooted. I say, therefore, that one discipline is mistress of the others —namely, theology, for which the others are integral necessities, and which cannot achieve its end without them. And it lays claim to their virtues and subordinates them to its nod and command.[18]

14. Augustine of Hippo, *De doctrina Christiana*, II. xl. 60–61, as quoted in Alister E. McGrath, *A Scientific Theology: Volume I: Nature* (Grand Rapids: Eerdmans, 2001), 14.
15. Augustine, *On Christian Doctrine*, trans. D.W. Robertson, Jr. (Indianapolis: Bobbs-Merrill, 1958), 75, as quoted by David C. Lindberg, 'Science as Handmaiden: Roger Bacon and the Patristic Tradition,' *Isis* 87(4), (1987): 523. For Latin and English parallel texts, cf. Roger P.H. Green (ed. and trans.), *Augustine: De doctrina Christana* (Cambridge: Clarendon Press, 1995).
16. Edward Grant, *The Foundations of Modern Science in the Middle Ages: Their Religious, Institutional and Intellectual Contexts* (Cambridge: Cambridge University Press, 1998), 72.
17. McGrath, *A Scientific Theology*, 7.
18. Roger Bacon, *The Opus majus of Roger Bacon*, ed. J.H. Bridges, 3 vols. (London: William and Norgate, 1900), III, 36, as cited in Lindberg, *The Beginnings of Western Science*, 226.

This was also the view of Aquinas. The *Doctor Angelicus* indeed established 'theology as an independent science' and 'conceded autonomy to philosophy (and, therefore, also, to natural philosophy) as a science,' but 'he still regarded it as subordinated to theology.'[19] For Thomas 'theology is to philosophy as the complete to the incomplete, the perfect to the imperfect.'[20] Theology thus held the upper hand.

Copernicus—'Astronomy is written for astronomers'

For many years Nicolas Copernicus hesitated to publish his work *On the Revolutions of the Heavenly Spheres* (1543). Only on his deathbed, persuaded by friends, did he finally allow its publication: 'I debated with myself for a long time whether to publish' the work 'about the revolutions of the spheres of the universe' which 'I wrote to prove the earth's motion.' As Copernicus admitted, 'the novelty and unconventionality of my opinion almost induced me to abandon completely the work which I have undertaken.'[21] Thus, although the 'conception of a heliocentric universe' was already 'fully worked out by about 1512,' he dared to offer it to the public eye only some thirty years later.[22] The reason is more than understandable, since this study announced the revolutionary hypothesis of the heliocentric system, claiming that according to 'the wisdom of nature' in

> the center of all [the universe] rests the sun. For who would place this lamp of a very beautiful temple in another or better place than this wherefrom it can illuminate everything at the same time? ... And so the sun, as if resting on a kingly throne, governs the family of stars which wheel around.[23]

The Polish astronomer and mathematician had of course every reason to fear the wrath of his contemporaries. His astronomical system contradicted the holy Scripture's vision of the earth as the center of the universe, along with its ultimate theological and teleological role of providing the site where

19. Grant, *The Foundations of Modern Science in the Middle Ages*, 74.
20. Lindberg, *The Beginnings of Western Science*, 232.
21. Nicolas Copernicus, *On the Revolutions*, trans. Edward Rosen (Baltimore: Johns Hopkins University Press, 1978), 3.
22. Allen G. Debus, *Man and Nature in the Renaissance* (Cambridge: Cambridge University Press, 1978), 81.
23. Nicolas Copernicus, *On the Revolutions of Heavenly Spheres*, trans. Charles G. Wallis (Amherst, NY: Prometheus Books, 1995), 3, 25–26. On the impact of Copernicus' cosmology on biblical interpretation and science in the early modernity, see Kenneth J. Howell, *God's Two Books: Copernican Cosmology and Biblical Interpretation in Early Modern Science* (Notre Dame: University of Notre Dame Press, 2002).

the drama of human salvation and redemption will be accomplished. Martin Luther (1483–1546), who vehemently rejected the heliocentric system, 'referred to Copernicus as that fool who wished "to reverse the entire science of astronomy."' Philipp Melanchthon (1497–1560), major Reformation theologian and associate of Luther in Wittenberg, likewise denounced Copernicus' new system of the world:

> The eyes are witness that the heavens revolve in the space of twenty-four hours. But certain men, either from the love of novelty, or to make a display of ingenuity, have concluded that the earth moves ... Now, it is a want of decency to assert such notions publicly, and the example is pernicious.[24]

John Calvin (1509–1564) was even more disparaging. He rebuked 'those who reprove everything and pervert the order of nature.' Some, he continues 'are so deranged, not only in religion but who in all things reveal their monstrous nature, that they will say the sun does not move, and that is the earth which shifts and turns.'[25] Later on, however, several Lutheran astronomers were crucial to the spread and development of Copernican views, among them Tycho Brahe (1546–1601) and Johannes Kepler. 'Reformed thought,' wrote Nebelsick not only 'renewed hope in history' but also 'tamed nature for investigation.'[26] Thus, according to Brahe, 'Copernicus nowhere offends the principles of mathematics, but he throws the earth, a lazy sluggish body unfit for motion, into a speed as fast as the ethereal torches.'[27] By the end of the seventeenth century, according to one study, 'many Protestants scientists were Copernicans, and many Protestant theologians seemed indifferent to the issue.'[28]

Copernicus's aim was not to 'reverse the entire science of astronomy,' as Luther claimed. He admitted that he became 'annoyed that the movements of the world machine, created for our sake by the best and most systematic Artisan of all, were not understood with greater certainty by the [natural] philosophers, who otherwise examine so precisely the most insignificant tri-

24. The quotations from Luther and Melanchthon appeared in Debus, *Man and Nature in the Renaissance*, 98.
25. John Calvin as cited in John H. Brooke, *Science and Religion: Some Historical Perspectives* (Oxford: Oxford University Press, 1991), 96.
26. Nebelsick, *The Renaissance, The Reformation and the Rise of Science*, xix.
27. Owen Gingerich, 'The Copernican Revolution,' in *Science and Religion: A Historical Introduction*, ed. Gary B. Ferngren (Baltimore: Johns Hopkins University Press, 2002), 100.
28. Edwards B. Davis and Michael P. Winship, 'Early Modern Protestantism,' in *Science and Religion: A Historical Introduction*, 122.

fles of this world.' It was at this juncture, where the traditional explanations provided by scholastic philosophers failed, that Copernicus 'began to consider the mobility of the earth,' and to see if he might be able to offer a better hypothesis 'for the revolution of the celestial spheres' based rather 'on the assumption of some motion of the earth.' He was thus seeking to provide a more adequate explanation of 'the general structure of the universe.' The hypothesis of the heliocentric framework for the planetary system, he knew, would be met by anger and rejection because it contradicted the traditional geocentric interpretation of certain passages in Scripture, and thus the whole worldview based on the biblical creation story of heaven and earth. Anticipating the objections to his heliocentric system, Copernicus constructed a new vision of science's authority and legitimacy to speak for nature and to read the mind of God in creation:

> Perhaps there will be babblers who claim to be judges of astronomy although completely ignorant of the subject and, badly distorting some passage of Scripture to their purpose, will dare to find fault with my undertaking and censure it.

He 'disregard[ed]' his critics 'even to the extent of despising their criticism as unfounded.' Copernicus held that religious thought and belief were no guarantee against ridiculous astronomical and cosmological errors, as the example of Lactantius (c. 250–325), an early Christian author, shows:

> it is not unknown that Lactantius, otherwise an illustrious writer but hardly an astronomer, speaks quite childishly about the earth's shape, when he mocks those who declared that the earth has the form of a globe. Hence scholars need not be surprised if any such person will likewise ridicule me. Astronomy is written for astronomers.[29]

Copernicus' words signified an important shift as regards science's right to interpret the secrets of nature. His attack on his critics, theologians and scholastic philosophers alike, is twofold: first, critics of the heliocentric system are ignorant of the science of astronomy; second, they distort scriptural passages in order to advance the traditional geocentric system. Not only do theological considerations not have priority in regard of astronomical arguments—'Astronomy is written for astronomers'—but, as Lactantius's example shows, they may lead to the childish conclusion that the earth is flat and hence to the rejection of the *antipodes*. (The belief in *Antipodes* signified adherence to the classical concept of a spherical earth, while the rejection of *Antipodes*, as in Lactantius, was used as an argument for a flat earth.)

Implied in Copernicus's response is the view that science and not reli-

29. Copernicus, *On the Revolutions*, 4–5.

gion should speak for nature. Since only astronomers could understand the language and method of astronomy, only they should deal with issues of astronomy. The field thus became a special sphere of scientific activity whose practitioners should be astronomers and not theologians. The beginnings of modern scientific thought thus went hand in hand with the denial of theology's role as the queen of sciences, at least in the realm of astronomy. This was indeed an essential precondition for the construction of modern scientific thought based on physics, or secondary causation, as Kepler's 'celestial physics' shows.

Kepler—The New *Physica Coelestis* (Heavenly Physics)

If Copernicus was the first to differentiate radically between astronomy and theology, Johannes Kepler went further, establishing the science of astronomy on new foundations which saw it further released from the traditional subservient to theology. Whereas the German mathematician and astronomer became a Copernican early in his life—'I built my whole astronomy upon Copernicus' hypothesis concerning the world'[30]—he himself initiated a radical shift in the understanding of celestial physics, or of the 'heavenly machine.'[31] As Kepler wrote, in his *Astronomia Nova* (1609), he established the science of astronomy on new scientific foundations—a new astronomical theory based on physical causes,[32] or *Physica Coelestis*, namely heavenly physics: 'What is the relation between this science [astronomy] and others?' asked Kepler:

> It is a part of physics, because it seeks the cause of things and natural occurrences, because the motion of the heavenly bodies is amongst its subjects, and because one of its purposes is to inquire into the form of the structure of the universe and its parts... To this end, [the astronomer] directs all his opinions, both by geometrical and by physical arguments, so that truly he places before the eyes an authentic form and disposition or furnishing of the whole universe.[33]

30. Johannes Kepler, 'Epitome of Copernican Astronomy' (1618), in Johannes Kepler, *Epitome of Copernican Astronomy & Harmonies of the World*, trans. Charles G. Wallis (Amherst, NY: Prometheus Books, 1995), 10.
31. Kepler, 'Letter to J.G. Herwart von Hohenburg,'16 February 1605, as quoted in A. Koestler, 'Johannes Kepler,' *Encyclopedia of Philosophy*, 8 vols. (New York: Macmillan, 1967), IV, 331.
32. Johannes Kepler, *New Astronomy*, 1609, trans. William H. Donahue (Cambridge: Cambridge University Press, 1992), 27.
33. Kepler, *Epitome of Copernican Astronomy*, as quoted in Peter Dear, *Revolutionizing the Sciences: European Knowledge and Its Ambitions, 1500–1700* (Princeton, NJ: Princeton University Press, 2001), 74.

This is the first time an astronomer had attempted to find the actual physical causes of the planetary movements, or to ascertain the physics of the solar system. Kepler's new principles of physics applied to the whole 'theatre of Nature,'[34] both in heaven and on earth, thus signifying that 'the earth itself and its moon must share a common physics with the planets.'[35] This led eventually to the destruction of the Aristotelian and the scholastic cosmos based on a theological teleology of hierarchical space, or on an essential ontological qualitative difference between heaven and earth. Hence, while Copernicus, following astronomical views traditional since Aristotle, still maintained a distinction between earthly and celestial phenomena, Kepler rejected qualitatively differentiated space together with the view that the universe is structured according to a hierarchy of values and entities. Instead, he was the first to look for 'a *universal law based on terrestrial mechanics* to comprehend the whole universe in its quantitative details.'[36] This was a new cosmological conception of the universe; whereas the Aristotelian cosmos was characterized by an essential dualism between heaven and earth, Kepler, and later Galileo and Descartes, 'broke down this dualism by postulating that physical causality permeated the entire universe.'[37] The whole world structure, heaven and earth alike, is subject to a single law of construction.

Kepler treated the earth as equal to the other planets, something very different from the traditional scholastic conception of the universe. A deeply religious man, the universe was for him a 'bright Temple of God.'[38] 'We astronomers,' he declared, 'are priests of the highest God in regard to the book of nature.'[39] Yet in his overarching goal, 'the reform of astronomy,'[40] Kepler freed himself 'from an animistic, teleologically oriented manner of thinking in scientific research.'[41] This stand had many important implications with regard to the relation between science and religion. The universe, Kepler believed, 'is properly intelligible in mathematical terms; its mathemat-

34. Kepler, *New Astronomy*, 33.
35. I. Bernard Cohen, *Revolution in Science* (Cambridge, MA: Harvard University Press, 1985), 129.
36. Gerald Holton, *Thematic Origins of Scientific Thought: Kepler to Einstein* (Cambridge, MA: Harvard University Press, 1988), 55. Emphasis in original.
37. A. Koestler, 'Johannes Kepler,' 332.
38. Kepler, 'To the Baron von Herberstein,' May 15, 1596, in Carola Baumgardt, *Johannes Kepler: Life and Letters* (New York: Philosophical Library, 1951), 32.
39. Kepler, 'To Herwart,' March 26, 1598, in Baumgardt, *Johannes Kepler*, 44.
40. Kepler, 'Dedication of the second edition of the Mysterium Cosmographicum,' 1621, in Baumgardt, *Johannes Kepler*, 128.
41. Albert Einstein, 'Introduction,' in Baumgardt, *Johannes Kepler*, 13.

ics, especially geometry, which allows insight into the mind of God, the Creator, and hence into the deepest realms of natural philosophy.' Further, 'the mathematics that structured astronomical theory was the very mathematics that underlay the structure of the universe itself.' Kepler was convinced that his astronomical discoveries 'brought him nearer to an intimate understanding of the structure of God's creation.'[42] The mathematical sciences now acquired authority and legitimacy in the study, understanding and interpreting of world phenomena.

The full title of Kepler's book manifests its great departure from scholastic thought: *New Astronomy Based on Causes, or Celestial Physics, treated by means of commentaries on the Motions of the Star Mars, from the Observations of Tycho Brahe*, 1609. It was a new astronomy based on the notion of physical causation, which took physical reality into account: 'I have mingled celestial physics with astronomy in this work,'[43] he wrote. Medieval, scholastic astronomy was descriptive in nature, supplying a purely descriptive geometry of the skies. Kepler's aim was 'chiefly to reform astronomical theory' by looking 'into celestial physics and the natural causes of the motions' of the planets.[44] He looked for a physics of the solar system, for 'physical causes.'[45] Instead of being described in traditional theological and teleological terms, the heavens are to be explained according to physical causes and causation: 'the heavenly machine is not a kind of divine, live being, but a kind of clockwork' whose motions are caused by simple 'material force.'[46] Kepler's new philosophy of celestial physics was very different from that of Dante, who wrote in the last line of *Paradiso* of 'the love [God's love] which moves the sun and the other stars.'

The basis of Kepler's new astronomy is causality which provides 'a philosophy or physics of celestial phenomena in place of the theology or metaphysics of Aristotle.'[47] The classic Aristotelian universe, which envisioned the planets moving in uniform motions and in perfect circles, was replaced by Keplerian astronomy which described the planets, like the earth, as floating freely in space and directed by mere physical forces or laws. Kepler's three laws of planetary motion were the first modern 'laws of nature'—laws dealing with natural phenomena, formulated in mathematical terms, and proposing uni-

42. Peter Dear, *Revolutionizing the Sciences*, 74, 76.
43. Kepler, *New Astronomy*, 47.
44. Kepler, *New Astronomy*, 48.
45. Kepler, *New Astronomy*, 48.
46. Kepler, 'Letter to J.G. Herwart von Hohenburg,' 16 February 1605, as quoted in Koestler, 'Johannes Kepler,' 331.
47. Kepler, 'To John Georg Brengger,' Oct. 4, 1607, in Baumgardt, *Johannes Kepler*, 75.

versal relations that regulate particular phenomena. This reduction of astronomy to physical causation transformed the traditional scholastic ties between astronomy and theology.[48] Kepler's was indeed a new science of astronomy, a 'new philosophy,'[49] which the metaphysical poet, John Donne, lamented in 'The First Anniversary' (1611): 'And new Philosophy calls all in doubt ... The Sun is lost, and th'earth, and no mans wit / Can well direct him where to look for it / And freely men confess that this world's spent, When in the Planets, and the Firmament / They seek so many new.' With the new astronomical philosophy, Donne felt, 'all cohaerence gone.'[50] The poet was right in his gloomy vision. Kepler's new astronomy led to the destruction of classical and medieval cosmology: the 'celestial spheres were gone,' and the 'planets moved independently through space.'[51]

The 'new philosophy' was not founded on theological convictions and persuasions. Its goal, said Kepler, was 'to reduce everything' in astronomy 'to physical origins.'[52] This led to the de-divinization of the heavens. As Kepler wrote in 1605:

> My aim is to show that the heavenly machine is not a kind of divine, live being, but a kind of clockwork ... insofar as nearly all the manifold motions are caused by a most simple magnetic, and material force, just as all motions of the clock are caused by a simple weight. And I also show how these physical causes are to be given numerical and geometrical expression.[53]

Furthermore: 'every detail of the celestial motions is caused and regulated by faculties of a purely corporeal nature, that is, magnetic.'[54] The celestial world is a physical machine, a machine driven by 'a single terrestrial force, in the image of clockwork.'[55] Kepler described this system in his *Astronomica Nova*, subtitled *Physica Coelestis*. Its radicalism is clear: he was the first to explain the mechanism of the solar system, the physics of the celestial

48. For the concept of causation in the early modern period, see John Henry, 'Causation,' in Ferngren, *Science and Religion: A Historical Introduction*, 130–142.
49. Kepler, 'Memorandum to Foreign Bookdealers,' in Baumgardt, *Johannes Kepler*, 134.
50. John Donne, 'The First Anniversary,' in *The Complete Poetry and Selected Prose of John Donne*, ed. Charles M. Coffin (New York: The Modern Library, 2001), 198–199.
51. Dear, *Revolutionizing the Sciences*, 77.
52. Kepler, 'To Peter Crüger,' Feb. 28, 1624, in Baumgardt, *Johannes Kepler*, 149.
53. Kepler, 'Letter to J.G. Herwart von Hohenburg,' 16 February 1605, as quoted in Koestler, 'Johannes Kepler,' 331.
54. Kepler, *New Astronomy*, 68.
55. Holton, *Thematic Origins of Scientific Thought*, 56.

machine, as governed by the laws of physical causality. It was a revolutionary conception of the universe, a mechanical vision in which 'the real world is a world of objects and their mechanical interactions.' In other words, Kepler's explanation of the physical operation of nature was based on mechanical principles defined in mathematical language. Like his contemporary Galileo, Kepler 'was trying to establish a new philosophical interpretation for "reality."'[56] His was 'a philosophy or physics of celestial phenomena in place of the theology or metaphysics of Aristotle.'[57]

The emergence of new astronomical thought and a novel understanding of the universe in the early modern period did not happen in a vacuum. Kepler wrote that 'the ancient astronomical hypotheses of Ptolemy' are 'to be completely removed' and 'cast out of the mind.' Indeed, he continued, 'I cannot do otherwise than to put solely Copernicus's opinion concerning the world in place of those hypotheses,' namely the heliocentric in place of the geocentric, 'and to persuade every one of it.'[58] The *New Astronomy* aroused strong negative reactions. Kepler wrote about 'those professors of the physical sciences who are irate with me, as well as with Copernicus' on account 'of our having shaken the foundations of science with the motion of the earth.'[59] And in regard to 'the opinions of the pious' [orthodox Christians] 'on these matters of nature,' or astronomy, Kepler, it is worth repeating, observed: 'I have just one thing to say: while in theology it is authority that carries the most weight, in [natural] philosophy it is reason.'[60]

The revolutionary thrust of Kepler's scientific thought is also evident in the appearance of new biblical interpretations. We have seen that Copernicus rejected the traditional literal reading of certain biblical passages which opposed the heliocentric system, claiming that the exegetes' distortion of scriptural passages led him to denounce such criticism of his ideas as unfounded.[61] Kepler thought the same, writing that 'many people fear the worst for themselves and for all earth's creature on account of the extreme rapidity of this motion [of the earth].' However, there are 'many more people who are moved by piety to withhold assent from Copernicus, fearing that falsehood might be charged against the Holy Spirit speaking in the scrip-

56. Holton, *Thematic Origins of Scientific Thought*, 60–61.
57. Kepler, 'To John Georg Brengger,' Oct. 4, 1607, in Baumgardt, *Johannes Kepler*, 75.
58. Kepler, *Harmonices Mundi* (1619), in Malcolm Oster, ed. *Science in Europe, 1500–1800* (New York: Palgrave, 2002), 56.
59. Kepler, *New Astronomy*, 46–47.
60. Kepler, *New Astronomy*, 66.
61. Copernicus, *On the Revolutions*, 4–5.

tures if we say that the earth is moved and the sun stands still.'[62] In response to these 'pious' people's criticism, Kepler offered new interpretations of the scriptural passages most troublesome for the heliocentric system, claiming that they posed no real challenge to Copernicus and his theory. These biblical interpretations in Kepler's 'Introduction' to his *New Astronomy* 'were to attain a wider readership in the seventeenth century than anything else he wrote. They were usually bracketed with [Galileo's] *Letter to the Grand Duchess* from their first appearance together in 1636.'[63]

Kepler rejected the literal interpretation of Scripture. He wrote: 'scripture also speaks in accordance with human perception when the truth of things is at odds with the senses,' as in the case of Psalm 19 where 'the sun is said to emerge from the tabernacle of the horizon like a bridegroom from his marriage bed, exuberant as a strong man for the race.' Here, as often elsewhere in Scripture, we should 'turn our eyes from physics to the aim of scripture.' The Bible does not deal with physics, or with physical descriptions of the world, hence 'you do not hear any physical dogma here.' Granted that Scripture does not pretend to provide any physical, astronomical theory, no one can claim that the teaching of the Bible opposes the Copernican or Keplerian system. For Scripture 'does not teach things of which men are ignorant,' such as astronomy, but its goal is 'to recall to mind something they neglect, namely God's greatness' in creation. Likewise, although it is said 'that Psalm 104, in its entirety, is a physical discussion' where 'God is said to have "founded the earth upon its stability, that it not be laid low unto the ages of ages,"' Kepler argues that in fact 'nothing could be farther from the Psalmist's intention than speculation about physical causes.'[64] By rejecting the literal meaning of Scripture, Kepler rejected the view that the Bible offers any reliable physical description of the world, or that it could provide 'objective' scientific truths about nature.

On the other hand, against orthodox Christian fears that the new astronomy was in conflict with 'the Holy Spirit speaking in scriptures,' Kepler observed, with joy, that the 'new philosophy' is rather glorifying God in his creation:

> I hope that, with me, he [the reader of *Astronomica Nova*] will praise and celebrate the Creator's wisdom and greatness, which I unfold for him in the more perspicacious explanation of the world's form, the investigation of causes, and

62. Kepler, *New Astronomy*, 59.
63. Ernan McMullin, 'Galileo on Science and Scripture,' in *The Cambridge Companion to Galileo*, ed. Peter Machamer (Cambridge: Cambridge University Press, 1998), 300.
64. Kepler, *New Astronomy*, 59–63.

> the detection of errors of vision. Let him not only extol the Creator's divine beneficence in His concern for the well-being of all living things, expressed in the firmness and stability of the earth, but also acknowledge His wisdom expressed in its motion, at once so well hidden and so admirable.

For Kepler the new 'physics of the heavens,' did not oppose religious belief in God's glory and power in the world. His endeavor tended rather to enhance God's greatness and goodness. Many people evidently did not accept these arguments, and Kepler attacked them in harsh words:

> But whoever is too stupid to understand astronomical science, or too weak to believe Copernicus without affecting his faith, I would advise him that, having dismissed astronomical studies and having damned whatever philosophical opinions he pleases, he mind his own business, and betake himself home to scratch in his own dirt patch, abandoning this wandering about the world.[65]

Kepler was fully conscious not only of the revolutionary ramifications of the new science of astronomy, but also of the negative reaction of orthodox Christians. He declared that any pious human being 'can be sure that he worships God no less than the astronomer.' But the astronomer has received a precious gift from God that lets him unveil the secrets of the heavens: to the astronomer, he wrote, 'God has granted the more penetrating vision of the mind's eye, and an ability and desire to celebrate his God above those things he has discovered.'[66] Since for Kepler the universe is a 'bright Temple of God,'[67] he held that 'astronomers are priests of the highest God in regard to the book of nature.'[68]

Who, then, can speak for nature? And who has the authority to explain and interpret its secrets? For Kepler the answer is clear—science based on reason, and not theology based on divine revelation. Accordingly, the Bible is not an authority on 'the form of the world' because you 'do not hear any physical dogma' in Scripture.[69] Yet, how this reflects on the authority of the Fathers of the Church and the Doctors of the Church, who explained the world of nature according to the literal interpretation of the Bible? To answer this question, Kepler found ample support in the history of the Church itself when

65. Kepler, *New Astronomy*, 59, 65–66.
66. Kepler, *New Astronomy*, 66.
67. Kepler, 'To the Baron von Herberstein,' May 15, 1596, in Baumgardt, *Johannes Kepler*, 32.
68. Kepler, 'To Herwart,' March 26, 1598, in Baumgardt, *Johannes Kepler*, 44.
69. Kepler, *New Astronomy*, 63.

pious Christian people made grave mistakes concerning the true nature of the world. As with Copernicus, the example of Lactantius came immediately to mind. Although 'Lactantius is pious,' wrote Kepler in irony, he nonetheless 'denied that the earth is round.' Likewise, 'Augustine is pious' though he 'denied the antipodes, and the Inquisition nowadays is pious, which, though allowing the earth's smallness, denies its motion.' The wisdom of the Doctors of the Church thus did not preclude grave mistakes in the explanation of nature, and being a pious man does not signify *ipso facto* a through understanding of the physical phenomena. On the contrary, Kepler pointed out, religion is not a guarantee for a true understanding of the world. Accordingly, 'with all due respect for the Doctors of the Church,' he claimed,

> I prove philosophically not only that the earth is round, not only that it is inhabited all the way around the antipodes, not only that it is contemptibly small, but also that it is carried along among the stars.[70]

These words contain the coming of age of the new science. In face of the formidable authority and power of the Church(es), Kepler dared to claim that its teachings as regards the heavens could not be accepted at face value because they were based on unfounded hypotheses. His own new science treats 'all of astronomy by means of physical causes rather than fictitious hypotheses.' As a result, he proudly declared: 'every detail of the celestial motions is caused and regulated by faculty of purely corporeal nature.'[71] The new 'physics of the heavens'[72] is thus radically different from that which Christians had been taught for many centuries. This difference evidently included the rejection of the notion of theology as the queen of sciences.

Galileo—The Book of Nature 'is written in the language of mathematics'

The life and career of Galileo coincided with that of Kepler, and the Italian physicist, astronomer and philosopher corresponded intermittently with the German mathematician and astronomer. They shared a belief in the Copernican system, advocated similar approach towards the relationship between science and religion, and were aware of the need to exclude theological considerations from scientific investigations. Emphasizing the need for experiment, observation and rigorous demonstration, and the applying of mathematical demonstrations to physical conclusions, the 'scientist who, more than any other, was first and foremost in advancing the new art of experimental sci-

70. Kepler, *New Astronomy*, 66.
71. Kepler, *New Astronomy*, 67–68.
72. Kepler, *New Astronomy*, 66.

ence was Galileo.'[73] Further, by stressing the need for 'demonstrated truths' as well as for 'experiences and rigorous proofs'[74] in order to explain the book of nature and thus correctly read the mind of God, Galileo's 'way of stating and solving problems in natural philosophy in mechanical ways became the model of natural philosophy for the seventeenth century.'[75]

Galileo's first contribution to astronomical observation appeared in 1610 under the name *Sidereus Nuncius* (*The Starry Messenger*). As compared with Kepler's massive *Astronomia Nova*, this was a rather small tract in which the Italian astronomer recounted his observations of celestial objects based on the use of the recently invented telescope, the 'Spyglass lately invented.'[76] In this work Galileo displayed his adherence to the Copernican system, claiming that 'the sun' stood at 'the center of the universe.'[77] In another work he described how the telescope helped him to shatter the Aristotelian heavens: 'we, thanks to the telescope, have brought the heavens thirty or forty times closer to us than they were to Aristotle, so that we can discern many things in them that he could not see.'[78] As with Kepler, new astronomical discoveries led Galileo to transform the traditional view of the world system:

> I have been led to the opinions and convictions that the surface of the moon is not smooth, uniform, and precisely spherical as a great number of philosophers believe it (and the other heavenly bodies) to be, but is uneven, rough, and full of cavities and prominences, being not unlike the face of the earth, relieved by chains of mountains and deep valleys.[79]

In contrast to Aristotle's view that heavenly bodies are smooth and spherical, Galileo's findings revealed a different heavenly physics of heavens, for the first time providing proof that the physics of heaven resembled that of the earth, a phenomenon which supported Copernicus's theory.

Galileo's observations led to the discovery of sunspots, something that added

73. Cohen, *Revolution in Science*, 135.
74. Galileo Galilei, *Letter to the Grand Duchess Christina ... Concerning the Use of Biblical Quotations in Matters of Science* (1615), in *Discoveries and Opinions of Galileo*, trans. Stillman Drake (New York: Anchor Books, 1957), 206–207.
75. Peter Machamer, 'Galileo's Machines, his Mathematics, and his Experiments,' in *The Cambridge Companion to Galileo*, 55.
76. Galileo, 'The Starry Messenger Revealing great, unusual, and remarkable spectacles, opening these to the consideration of every man, and especially of philosophers and astronomers' (1610), in *Discoveries and Opinions of Galileo*, 21.
77. Galileo, 'The Starry Messenger,' 24.
78. Galileo, *Dialogue Concerning the Two Chief World Systems – Ptolemaic & Copernican* (1632), trans. Stillman Drake (Berkeley: University of California Press, 1967), 56.
79. Galileo, 'The Starry Messenger,' 31.

to the weakening of classical astronomical thought: 'if blemishes could appear and disappear on the face of the sun itself, the incorruptibility and inalterability of the heavenly bodies was destroyed.'[80] As with the discovery of the surface of the moon, sunspots revealed that the physics of heaven did not differ much from that of the earth, something that radically contradicted Aristotle's views.[81] Aristotle argued that the celestial region is incorruptible and changeless because it was made from perfect matter, hence unalterable, in contrast to the four elements of the terrestrial region—earth, water, air and fire—which are alterable: 'The Aristotelian heavens were held to be perfect and substantively unchanging; all they did was to wheel around eternally, exhibiting no regeneration of new things or passing away of old.'[82] Galileo's sunspots were therefore 'a momentous discovery at the time' since the Aristotelians maintained that 'nothing could change in the heavens, and surely not the eternal and immutable Sun.'[83] Galileo concluded his *History and Demonstration Concerning Sunspots and Their Phenomena* (1613) by saying: 'in order that we may harvest some fruit from the unexpected marvels that have remained hidden until this age of ours,' such as sunspots, 'it will be well if in the future we once again lend ear to those wise philosophers whose opinion of the celestial substance differed from Aristotle.'[84]

Galileo knew that 'in making the celestial material alterable, I contradicted the doctrine of Aristotle.' Likewise, he rejected the Aristotelian essential dualism between heavens and earth. One may interpret heavenly phenomena by making an analogy with earthly ones because the celestial matter is no different from the terrestrial. On the basis of these and other findings, Galileo argued 'all human reasoning must be placed second to direct experience.' The power of authority based on tradition and history was thus undermined in the realm of science in face of knowledge based on direct experience involving observation and experiment. Scientists should 'give assent to propositions that depend upon manifest observations' and not to 'opinions repugnant to the senses and supported only by probable reasons.'[85] The knowledge of nature has its own method of reasoning—observations, experiments, demonstrated truths—and these should have the priority in understanding the phenomena

80. Drake, *Discoveries and Opinions of Galileo*, 83.
81. See Grant, *The Foundations of Modern Science in the Middle Ages*, 63–69.
82. Dear, *Revolutionizing the Sciences*, 70.
83. William Shea, 'Galileo's Copernicanism: The Science and the Rhetoric,' in *The Cambridge Companion to Galileo*, 224.
84. Galileo, *Letters on the Sunspots*, 1613, in *Discoveries and Opinions of Galileo*, trans. Stillman Drake, 118.
85. Galileo, *Letters on the Sunspots*, 1613, 118.

of the world over knowledge based on undemonstrated revealed truths.

Galileo's contributions to the development of the 'new philosophy' encountered very strong criticism, and he had to deal extensively with the issue of the proper relation of science to religion or revelation. His views on the issue appeared in his *Letter to the Grand Duchess Christina ... Concerning the Use of Biblical Quotations in Matters of Science* (1615). 'The novelty of these things,' Galileo wrote to the Duchess[86] about his new astronomical discoveries, 'as well as some consequences which followed from them,' stood in great contrast 'to the physical notions commonly held among academic philosophers,' that is, scholastic philosophers. It was quite natural that 'no small number of professors' thought that he, Galileo, 'placed these things in the sky to upset nature and overturn the sciences.' In face of astronomical discoveries scholastic professors rather showed 'a greater fondness for their own opinions than for truth' and tried 'to deny and disprove the new things.' At this important juncture, where new astronomical findings about the heavenly bodies were colliding with the teaching of the Church, these professors turned to the Bible, 'sprinkling' their charges against the 'new philosophy' with 'passages taken from places in the Bible which they had failed to understand properly, and which were ill suited to their purpose.'[87]

In his letter to the Duchess Christina, Galileo declared his adherence to the Copernican system: 'I hold the sun to be situated motionless in the center of the revolution of the celestial orbs while the earth rotates on its axis and revolves about the sun.' Although he knew that 'this position' refuted 'the arguments of Ptolemy and Aristotle,' he adopted it. What he was not willing to accept was that the people who opposed the 'new philosophy' resolved 'to fabricate a shield for their fallacies out of the mantle of pretended religion and the authority of the Bible.'[88] He thus turned the denunciations of himself accusing his opponents of subverting religion and the authority of Scriptures, hence of using in vain the name of religion and of the sacred Bible:

> They make a shield of their hypocritical zeal for religion. They go about invoking the Bible, which they would have minister to their deceitful purposes. Contrary to the sense of the Bible and the intention of the holy fathers.[89]

Reading the mind of God was associated with the understating of his Word,

86. Originally the Duchess of Lorraine, on marrying Ferdinand I de' Medici (Galileo's patron at the University of Pisa), she became the Grand Duchess of Tuscany.
87. Galileo, *Letter to the Grand Duchess Christina*, 175.
88. Galileo, *Letter to the Grand Duchess Christina*, 177.
89. Galileo, *Letter to the Grand Duchess Christina*, 179.

and the understanding of the book of nature became associated with the right interpretation of Scripture. Here Galileo, like Copernicus and Kepler, entered into theological territory. With whom, then, did authority lie in the interpretation of controversial passages in Scripture? All these forerunners of modern science believed that theologians had no business assessing the values of astronomical arguments. Further, Galileo's views, like those of Copernicus and Kepler, implied that because the new cosmology contradicted the literal sense of the words of Scripture, the proponents of the 'new philosophy' arrogated 'to themselves an authority in interpreting Scripture that belonged properly only to the Church, speaking through its bishops and theologians.'[90]

Against theologians and scholastic philosophers who claimed that the Bible provides true descriptions of physical phenomena, Galileo declared that 'the primary purpose of the sacred writings' is 'the service of God and the salvation of souls.' Since, as Kepler argued, no physical dogma is taught in Scripture, it is not intended to serve as a source of knowledge about the phenomena of the world; the Bible is not the place to look for the confirmation of scientific theories, such as the Copernican system. A 'discussion of physical problems' ought 'to begin not from the authority of scriptural passages, but from sense-experiences and necessary demonstrations.' The answer to the question who may speak for nature is clear—science based on experience, experiment and demonstrations, and not religious authority based on sacred writings: 'nothing physical which sense-experience sets before our eyes, or which necessary demonstrations prove to us, ought to be called in question (much less condemned) upon the testimony of biblical passages.'[91] Galileo thus constructed a special sphere for scientific activity, devoid of any teleological and theological considerations, because science is founded on a different mode of thought and reasoning. This was indeed a momentous development in the long relationship between science and religion.

Scientific 'demonstrated truth' should be used in the study of nature because there are 'sciences of which but the faintest trace' is 'to be found in the Bible.' Chief among them is astronomy, of which 'so little is found' in Scripture. The holy Scriptures do not pretend to teach us about the 'phenomena of the celestial bodies.' On the contrary. 'Far from pretending to teach us the constitution and motions of the heavens and the stars, the authors of the Bible intentionally forbore to speak of these things.' The reason was simple: the 'Holy Spirit did not desire that men should learn things that are

90. McMullin, 'Galileo on Science and Scripture,' 300.

91. Galileo, *Letter to the Grand Duchess Christina*, 182–183.

useful to no one for salvation.' Teleological and theological considerations therefore should not be involved in the science of astronomy. Galileo used all these arguments to advance his ultimate persuasion that 'the Holy Ghost did not intend to teach us whether heaven moves or stands still.'[92] Or, in the words of the epigram composed by his contemporary, Cardinal Baronius (1538–1607): 'the intention of the Holy Ghost is to teach us how one goes to heaven, not how heaven goes.'[93] The study of nature is not taught in the Bible since the purpose of the Scriptures is salvation. On this reasoning Scripture loses its traditional role as the exclusive source and locus of all possible knowledge about the world and the universe. Galileo placed limitations on scriptural authority, arguing that the Bible has no special say where nature is concerned, and no particular legitimacy to speak for nature. Instead of looking to the Scriptures in order to understand how heaven moves, Galileo insisted that only 'necessary demonstrations and sense experiences ought to be respected in physical conclusions.'[94] But science was not opposed to religion because each possessed its own distinct sphere in which its authority and legitimacy were fully asserted—the Bible over the way to salvation, and science over the reading and understanding of the mind of God in the grand book of nature. Galileo concluded:

> nor is God any less excellently revealed in Nature's actions than in sacred statements of the Bible. Perhaps this is what Tertullian meant by these words: We conclude that God is known first through Nature, and then again more particularly by doctrine.[95]

Since God was revealed in his works as well as in his words, nature became a legitimate, authoritative source for the knowledge of God. Science, as Galileo wrote in 1632 in his *Dialogue Concerning the Two Chief World Systems—Ptolemaic & Copernican*, may 'discover the work of His hands' so that 'we may recognize and thereby so much the more admire His greatness.'[96] Accordingly, he warned 'not to permit anyone to usurp scriptural texts and force them in some way to maintain any physical conclusion to be true' because this leads to closing 'the road to free philosophizing about mundane and physical things, as if everything had already been discovered and

92. Galileo, *Letter to the Grand Duchess Christina*, 184–185.
93. Cardinal Baronius as quoted in Drake, *Discoveries and Opinions of Galileo*, 186, n. 8.
94. Galileo, *Letter to the Grand Duchess Christina*, 186.
95. Pietro Redondi, 'From Galileo to Augustine,' in *The Cambridge Companion to Galileo*, 190.
96. Galileo, *Dialogue Concerning the Two Chief World Systems*, 464.

revealed with certainty.'[97] However, given that the secrets of nature are being constantly unveiled by the power of science, as evidenced in astronomical discoveries, the book of nature 'stands continually open to our gaze'[98] and inquiry. Galileo speaks here as the experimental scientist. Scientists, he wrote, 'apply mathematical demonstrations to physical conclusions.'[99] And in natural philosophy any accepted 'physical conclusion' may 'at some future time' be found invalid according to 'the senses and demonstrative or necessary reasons.' No one, therefore, 'should close the road to free philosophizing about mundane and physical things.'[100]

Different methods of reasoning thus led to different approaches in theology and science. While the first was based on the power of revelation, the second was based on 'demonstrative or necessary reasons.' Yet people 'who are unable to understand perfectly both the Bible and the sciences' tended to confuse the two. By 'glancing superficially through the Bible,' they arrogated 'to themselves the authority to decree upon every question of physics on the strength of some word which they have misunderstood, and which was employed by sacred authors for some different purposes.'[101] Rather than claim that science subverts traditional religious thought, Galileo attacked those who confounded their wrong readings of the Scriptures with their poor understanding of physics. In the end, however, because the Bible does not offer any physical theory, no one may attack the new philosophy of astronomy on the basis of some scriptural passages.

Galileo rejected the notion of theology as the queen of sciences in order to secure science's autonomy and thus to pave the way for scientific progress. First he turned against the 'lay writers' and 'theologians' who by attacking him 'pretend to the power of constraining others by scriptural authority to follow in physical dispute.' These people argued that:

> since theology is the queen of all sciences, she need not bend in any way to accommodate herself to the teaching of less worthy sciences which are subordinate to her; these others [sciences] must rather be referred to her as to their supreme empress, changing and altering their conclusions according to her statues and decrees … that if in the inferior sciences any conclusion should

97. Galileo, *Letter to the Grand Duchess Christina*, 187.
98. Galileo, *The Assayer*, 1623, in *Discoveries and Opinions of Galileo*, trans. Stillman, 237–238.
99. Galileo as quoted in Machamer, 'Galileo's Machines, his Mathematics, and his Experiments,' 68.
100. Galileo, *Letter to the Grand Duchess Christina*, 187.
101. Galileo, *Letter to the Grand Duchess Christina*, 190.

> be taken as certain in virtue of demonstrations or experiences, while in the Bible another conclusion is found repugnant to this, then the professors of this science [should] undo their proofs and discover the fallacies in their own experiences.[102]

Secondly, Galileo directly attacked the medieval, scholastic contention that 'entitled sacred theology' the 'title of "queen"' of the sciences. This appellation can be explained in two different ways. First, theology may deserve it 'by reason of including everything that is learned from all other sciences and establishing everything by better methods and with profounder learning.' Galileo rejects this meaning altogether; no theologians 'will say that geometry, astronomy, and medicine are much more excellently contained in the Bible than they are in the books of Archimedes, Ptolemy, Boethius and Galen.'[103]

The second sense is related to 'its subject and the miraculous communication of divine revelation conclusions' concerning 'chiefly the attainment of eternal blessedness.' Accordingly,

> Let us grant then that theology is conversant with the loftiest divine contemplation, and occupies the regal throne among sciences by dignity. But acquiring the highest authority in this way, if she does not descend to the lower and humbler speculations of the subordinate sciences and has no regard for them because they are not concerned with blessedness, then her professors should not arrogate to themselves the authority to decide on controversies in professions which they have neither studied nor practiced. Why, this would be as if an absolute despot, being neither a physician nor an architect but knowing himself free to command, should undertake to administer medicine and erect buildings according to his whim—at grave peril of his poor patients' lives, and the speedy collapse of his edifices.

As far as divine things are concerned, theology was indeed superior to all other sciences, but as regards natural phenomena, its traditional role was no longer secure in face of the new scientific thought. In his desire to deny theology the status of 'queen' of sciences, and to release science from its tutelage to theology, Galileo begged the reader 'to consider with great care the difference that exists between doctrines subject to proof and those subject to opinion.' Theology concerns transcendent issues, science mundane ones, hence the first deals with salvation and the second with the explanation of nature. Granted this distinction, 'demonstrated physical conclusions need not be subordinated to biblical passages, but the latter must rather be shown not to interfere

102. Galileo, *Letter to the Grand Duchess Christina*, 191–192.

103. Galileo, *Letter to the Grand Duchess Christina*, 192–193.

with the former.'[104]

No other man of that time so boldly and fiercely attacked the cherished concept of theology as the queen of sciences. Indeed, being related to salvation, the revealed, undemonstrated axioms of faith had priority over the demonstrated truths of reason. But concerning 'the grand book, the universe,' demonstrated truths had priority over revealed. For 'the book cannot be understood unless one first learns to comprehend the language and read the letters in which it is composed.' The book of nature 'is written in the language of mathematics,' and 'its characters are triangles, circles, and other geometric figures without which it is humanly impossible to understand a single word of it; without these, one is wandering in a dark labyrinth.'[105] Mathematics thus became essential to any understanding of nature. Theological considerations cannot unveil the secrets of nature since the book of nature is written in the 'language of mathematics,' a language that since Galileo's time has become the essential characteristic language of scientific thought. As a specific sphere of inquiry, science now possessed its own medium—mathematics—with which to describe natural phenomena. Moreover, by 'subordinating mechanical laws of nature to divine guidance, mathematical physics provided the key to knowledge of God.'[106]

Conclusion

The scholastic view of theology as the queen of sciences, and science as her handmaiden, continued well into the seventeenth century. With the construction of modern scientific thought during the sixteenth and seventeenth centuries, the relationship between science and religion became more and more problematic and with it theology's role as the queen of sciences. As far as divine things were concerned, theology was held superior to all other sciences, but as regards natural phenomena, natural philosophers gradually denied theology's regal role in explaining how nature works, and ceased to consider natural science as 'handmaiden.' Intrinsic to this process was the history of the mathematical sciences. Until the sixteenth century, mathematics was not considered essential to scientific thought: 'Aristotelian physics aimed at understanding qualitative processes. Quantities were at best peripheral to it, because they failed to speak of the essence of things.'[107] But as the thought

104. Galileo, *Letter to the Grand Duchess Christina*, 193–195.

105. Galileo, *The Assayer*, 237–278.

106. Redondi, 'From Galileo to Augustine,' in Machamer, *Cambridge Companion to Galileo*, 201.

107. Dear, *Revolutionizing the Sciences*, 65.

of Copernicus, Kepler and Galileo shows, the emergence of modern scientific thought was inseparable from the development of mathematics. The mathematical sciences became a way of learning about the natural world, seriously challenging scholastic philosophy. It is ironic that centuries after the dethroning of theology, Carl Friedrich Gauss (1777–1855), mathematician and scientist, sometimes known as 'the prince of mathematics,' re-invented the concept and conferred the title 'queen of sciences' (*Königin der Wissenschaften*) on mathematics, a title which the mathematical sciences still enjoy today.

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