Univ. Press, 1948), pp. 217–223. For analysis see Clagett, *Greek Science in Antiquity*, pp. 169–176.

84. Many scholars have pointed out that in antiquity the term *philosophy* came increasingly to denote the quest for happiness or salvation.

85. Above, n. 54.

86. For discussion of the influence of Greek thought on Christian doctrine see Edwin Hatch, *The Influence of Greek Ideas on Christianity*, ed. Frederick C. Grant (New York: Harper & Brothers, 1957); Timothy, *Early Christian Apologists*, pp. 81–98.

2

Science and Theology in the Middle Ages

Edward Grant

Science and theology were never more closely interrelated than during the Latin Middle Ages in Western Europe. In this occasionally stormy relationship, theology was clearly the dominant partner. Limited challenges to that dominance occurred only when a sufficiently powerful natural philosophy was available to offer alternative interpretations of cosmic structure and operation. Conflict between science and theology rarely arose in the technical sciences, but developed in that part of natural philosophy concerned with the larger principles of cosmic operation, especially where theology and science sought to explain the same phenomena.[1] Prior to the twelfth century, when the scientific fare of Latin Christendom was meager, science lacked powerful metaphysical foundations and consisted of little more than a few of Aristotle's logical treatises, some medical works, two-thirds of Plato's *Timaeus*, a few astrological books, and, especially, a series of Latin encyclopedic handbooks written by Pliny, Solinus, Calcidius, Macrobius, Martianus Capella, Boethius, Cassiodorus, Isidore of Seville, and the Venerable Bede. An important feature of this body of secular learning was the famous seven liberal arts with their twofold division into language and mathematics or mathematical science, the former consisting of grammar, rhetoric, and dialectic (or logic) and designated by the term *trivium*, the latter embracing arithmetic, geometry, astronomy, and music, collectively known as the *quadrivium*.

The narrow conception of science embodied in the *quadrivium* of the seven liberal arts was expanded into the broader sense of natural philosophy during the twelfth and thirteenth centuries when, in the course of an unparalleled period of translating activity from Arabic and Greek into Latin, the bulk of Greek science and natural philosophy was finally introduced into Latin Christendom, some eleven hundred years after the birth of Christianity.

SCIENCE AS HANDMAIDEN TO THEOLOGY

Through much of the Middle Ages, science was assigned the status of a "handmaiden to theology" (*philosophia ancilla theologiae*), a role first envisaged for it by Philo Judaeus in the first century A.D., subsequently adopted by Clement of Alexandria (ca. 150–ca. 215) and Saint Augustine (354–430) in late antiquity, and fully reinforced centuries later by Hugh of Saint-Victor (d. 1141) and Saint Bonaventure (1221–1274). According to the handmaiden concept, science was not pursued for its own sake but only for the aid it could provide in the interpretation of Holy Scripture. Saint Bonaventure even devoted a special treatise to the ancillary and subsidiary role of the arts to theology. In this work, which he titled *On Retracing the Arts to Theology (De reductione artium ad theologiam)*, Bonaventure interpreted the "arts" (*artes*) as almost synonymous with philosophy and science and believed that he had demonstrated "how all divisions of knowledge are handmaids of theology," for which reason "theology makes use of illustrations and terms pertaining to every branch of knowledge." It was the purpose or "fruit of all sciences, that in all, faith may be strengthened, [and] *God may be honored*."[2] The glorification of God was the ultimate goal of the scientific study of nature. Some two centuries earlier, Peter Damian (1007–1072) also reflected patristic and early medieval attitudes toward the relationship of God and nature. Because God created the world from chaos, Damian considered Him the direct and immediate cause of nature's laws and its ordered beauty.[3] God encourages the study of the external, visible world with a twofold purpose: to provide in us the contemplation of its invisible, spiritual nature, so that we should better love and adore Him, and to enable us to gain dominion over it as described in Psalms 8:6–9.[4] Achievement of these goals is made possible by the sciences of number and measure in the *quadrivium*.[5] For Peter Damian, as for Bonaventure later, the study of nature and its laws was not an end in itself, pursued merely for the sake of knowledge. It had to serve the higher needs of religion and theology. Under these circumstances the secular sciences could hardly avoid the status of handmaidens.

REVOLT OF THE HANDMAIDENS: NATURAL PHILOSOPHY CHALLENGES THEOLOGY

The subservience of science to theology, however, was always relative. It was more complete during the early Middle Ages than later, a condition attributable, in no small measure, to the enfeebled state of natural philosophy in the five or six formative centuries of the early medieval period. The bulk of Greek science and philosophy was simply absent from the corpus of secular learning that passed for science. So low was the level of science in this period that it posed no threat whatever to Christian tradition and doctrine. With the exception of Plato's *Timaeus*, most of it was encyclopedic, unintegrated, and frequently confused or contradictory. Devoid of cohesion or guiding principles, it could inspire little by way of new interpretations or insights about the nature of the world that might prove subversive of Christianity.

By the twelfth century, significant changes were under way that would eventually challenge theology's interpretation of the cosmos and the God who created it. The threat to theology and the church did not derive from astrology or magic, which, though potentially dangerous, were successfully contained in the Middle Ages. It came from Greek natural philosophy and science, initially in its benign Platonic and Neoplatonic forms in the twelfth century and then in its powerful and truly menacing Aristotelian form in the thirteenth century. The beginnings of this momentous process are already apparent in the enthusiastic study of Plato's *Timaeus* in the twelfth century. Evidence of significant change is readily available. Inspired perhaps by Honorius of Autun's (fl. 1122) joyous sentiment that "all of God's creation gives great delight to anyone looking upon it,"[6] a sentiment shared by his contemporary, Thierry of Chartres (d. ca. 1155),[7] and by earlier authors such as Peter Damian, scholars came to investigate nature for its own sake. William of Conches (ca. 1080–ca. 1154), for whom physical laws took precedence over ecclesiastical authority, reflected the new attitude when he denounced those who, "ignorant themselves of the forces of nature and wanting to have company in their ignorance . . . don't want people to look into anything; they want us to believe like peasants and not to ask the reason behind things."[8] To explain causes and phenomena by mere appeal to God's omnipotence or a biblical passage was now tantamount to a confession of ignorance.[9] It was the obligation of philosophy, not Holy Scripture, to teach about nature and its regular causes and events. A newfound confidence in human reason and sensory experience had emerged.

Even the Bible, especially the creation account of Genesis, had to conform to the demands of physical science. The bold new emphasis on rational inquiry, with which the names of Adelard of Bath, Peter Abelard, William of Conches, Bernard Silvester, Clarenbaldus of Arras, and others in the twelfth century were associated, marked the beginning of an unsuccessful, though vigorous, attempt to separate science from theology. Separation, however, did not signify that science was to be pursued solely for its own sake. On the contrary, its application to the exegesis of Holy Scripture and to the elucidation of theological problems would produce a role reversal: science began to encroach upon theology. Thus were the seeds of a science-theology confrontation planted, the bitter fruits of which would grow to maturity in the thirteenth century following upon the introduction of Aristotle's scientific works, which formed the crucial core of the new Greco-Arabic science that entered Western Europe. By the early thirteenth century, Latin translations (from Arabic) of Aristotle's scientific, logical, and metaphysical works had taken Europe by storm. No match for the depth and diversity of the Aristotelian treatises with their elaborate scientific methodology and foundational principles, Plato's *Timaeus*, which had formed the basis and inspiration of the twelfth-century worldview, soon fell into abeyance.

Aristotle's treatises on physics, metaphysics, logic, cosmology, the elements, epistemology, and the nature of change furnished the Middle Ages with its conception of the structure and operation of the physical world. They assumed this fundamental role because their introduction into Western Europe coincided with, and probably contributed toward, the establishment of that uniquely medieval institution, the university. For approximately 450 years, from 1200 to 1650, the universities of Western Europe emphasized a philosophical and scientific curriculum based on the works of Aristotle, whose logic and natural philosophy were studied by all who received the master of arts degree. Since the latter was usually a prerequisite for entry into the higher faculty of theology, most theologians were well acquainted with contemporary science.

The impact of Aristotle's thought on the late Middle Ages cannot be overestimated. For the first time in the history of Latin Christendom, a comprehensive body of secular learning, rich in metaphysics, methodology, and reasoned argumentation, posed a threat to theology and its traditional interpretations. Where Plato's creation account in the *Timaeus*, which featured a creator God who sought to share his goodness by fabricating a world from preexistent and coeternal matter and form, was reasonably compatible with Christianity, Aristotle's cosmic system, which assumed a world without beginning or end and a deity who had no knowledge of that world, was not. When to these difficulties were added those concerning the soul (it apparently perished with the body) and a strong tendency to employ naturalistic and even deterministic modes of explanation, it becomes obvious that the Aristotelian world system was not readily reducible to the status of a theological handmaiden. While numerous theologians and almost all arts masters eagerly embraced the new Aristotelian learning at the University of Paris, which possessed the most prestigious and powerful faculty of theology in all Christendom, there was a growing uneasiness amongst more traditionally minded theologians, as evidenced by a ban on Aristotle's natural books issued in 1210 and 1215 and an abortive attempt to expurgate them in 1231.[10] All such attempts were in vain, and by 1255 Aristotle's works were not only officially sanctioned but constituted the core of the arts curriculum.[11]

Those who had hoped for a harmonious relationship between theology and philosophy were to be bitterly disappointed. During the 1260s and early 1270s a fundamental split developed. On the one side were radical arts masters and liberal theologians who found Aristotle's philosophy essential to a proper understanding of God and his creation. Opposed to them were traditional theologians for whom significant aspects of Greek philosophy were dangerously subversive to the Christian faith.[12] Typified by the likes of Siger of Brabant and Boethius of Dacia, the more radical arts masters perceived Aristotle's natural philosophy as the indispensable key to a proper interpretation of the cosmos and concluded that philosophy was not only independent of theology but at least its equal and perhaps its superior. Although they would surely have denied it equality, many theologians regarded philosophy as worthy of independent study and assigned it a central role. The most illustrious member of this group was undoubtedly Thomas Aquinas (ca. 1225–1274), who considered theology the highest science because of its reliance on revelation. Without revelation the truth of the metaphysics that philosophers might devise would be incomplete and imperfect.[13] Yet Aquinas not only embraced philosophy with enthusiasm but regarded Aristotle as the greatest of philosophers, one who had achieved the highest level of human thought without the aid of revelation.[14] Rightly understood, philosophy, which included secular science, could not contradict theology or faith.[15]

Suspicious of the emphasis on philosophy and secular learning that had occurred during the 1260s and fearful of the application of Aristotelian philosophy to theology, traditional and conservative theologians, inspired by Saint Bonaventure, sought to stem the tide by outright condemnation of ideas they considered subversive. Since repeated warnings of the inherent dangers of secular philosophy and the perils of its application to theology had been of little avail,[16] the traditional theologians, many of whom were neo-Augustinian Franciscans, appealed to the bishop of Paris, Etienne Tempier, who responded in 1270 with a condemnation of 13 propositions, which was followed in 1277 by a massive condemnation of 219 propositions, any one of which was held at the price of excommunication.

THE IMPACT OF THEOLOGY ON SCIENCE

Controversial and difficult to assess, the Condemnation of 1277 looms large in the relations between theology and science. Except for articles directed specifically against Thomas Aquinas, which were nullified in 1325, the condemnation remained in effect during the fourteenth century and made an impact even beyond the region of Paris, where its legal force was confined. Hastily compiled from a wide variety of written and oral sources, the 219 condemned errors were without apparent order, repetitious, and even contradictory.[17] Orthodox and heterodox opinions were mingled indiscriminately.[18] A number of the errors were relevant to science. Of these, many were condemned in order to preserve God's absolute power (*potentia Dei absoluta*), a power that natural philosophers were thought to have unduly restricted as they eagerly sought to interpret the world in accordance with Aristotelian principles.[19] If the condemned errors accurately reflect contemporary opinion, some natural philosophers were prepared to deny the divine creation of the world, that God could create more than one world, that he could move the world in a straight line, leaving behind a void space, that he could create an accident without a subject, and so on. In denying to God the capacity to perform these and other actions that were impossible in the physical world as conceived by Aristotle and his followers, philosophers were severely constraining God's power. The theologians who compiled the list of condemned errors sought to curb the pretensions of Aristotelian natural philosophy by emphasizing the absolute power of God to do whatever He pleased short of a logical contradiction. Indeed, article 147 made this quite explicit by rejecting the claim "that the absolutely impossible cannot be done by God or another agent," which is judged "an error, if impossible is understood according to nature."[20] With respect to nature, then, all had to concede that God could do things that were contrary to prevailing scientific opinion about the structure and operations of the cosmos. In short, God could produce actions that were naturally impossible in the Aristotelian worldview. It was thus Aristotelian natural philosophy on which the Condemnation of 1277 pressed most heavily. If we can judge from those condemned errors which asserted that "theological discussions are based on fables," that "nothing is known better because of knowing theology," that "the only wise men of the world are philosophers,"[21] and that "there is no more excellent state than the study of philosophy,"[22] the Condemnation of 1277 may have served as a vehicle of sweet revenge for the theologians who compiled it. It offered an opportunity to humble the professional Aristotelian natural philosophers from whom those hostile sentiments derived.

The Paris condemnation of 219 diverse errors in theology and natural philosophy was a major event in the history of medieval natural philosophy. Whatever the doctrinal and philosophical disputes, or personal and group animosities that produced it, emphasis on God's absolute power was its most potent feature. Although the doctrine of God's absolute power was hardly new in the thirteenth century,[23] the challenge from Aristotelian natural philosophy and physics, and Greco-Arabic thought generally, conferred on it a new significance. The growing tendency prior to 1277 was to interpret cosmic phenomena in accordance with natural causes and explanatory principles derived from Aristotelian physics and cosmology. After 1277, appeals to God's absolute power were frequently introduced into physical and cosmological discussions. Whether by implication or explicit statement, many of the articles of the condemnation proclaimed God's infinite and absolute creative and causative power against those who would circumscribe it by the principles of Aristotelian natural philosophy. As a consequence, natural impossibilities, usually cast in the form of "thought experiments," were hereafter entertained with increasing frequency and occasionally with startling consequences. The supernatural alternatives considered in the aftermath of the condemnation of 1277 conditioned Scholastics to contemplate physical possibilities outside the ken of Aristotelian natural philosophy, and frequently in direct conflict with it. As the means of achieving these hypothetical possibilities, God's absolute power was usually invoked. Indeed, hypothetical possibilities based upon supernatural actions became a characteristic feature of late medieval Scholastic thought. To illustrate these tendencies we need only consider two articles concerned with the possibility of other worlds and the movement of our own.

Both Aristotle and the Bible agreed that only one world existed. With a variety of arguments Aristotle had demonstrated the impossibility of other worlds. For some of his enthusiastic medieval followers it was an easy inference that God could not create other worlds even had He wished to do so. Thus a limitation was placed upon divine power, a limitation that was condemned in article 34, which threatened excommunication to any who held that God could not possibly create more than one world. Although it was in no way required to believe that God had created a plurality of worlds—indeed, no one in the Middle Ages did so believe—but only that He could do so, the effect of article 34 was to encourage examination of the conditions and circumstances that would obtain if God had indeed created other worlds. In this spirit a number of Scholastic authors formulated arguments that sought to make the possible existence of other worlds intelligible. Sometime around 1295 Richard of Middleton (d. ca. 1300) argued in his commentary on Peter Lombard's *Sentences* that if God created other worlds identical with ours, the very kind Aristotle had discussed, each of them would behave just as ours does, since no good reasons could be adduced for supposing otherwise. Hence each world would be a self-contained, closed system with its own center and circumference.[24] It surely followed that if God did indeed create more than one world, no unique and privileged center would exist, an inference that subverted the foundation of Aristotle's cosmology, namely that the center and circumference of our world are unique. This extraordinary result, which would be repeated in the fourteenth century by the likes of William of Ockham, John Buridan, and Nicole Oresme, was achieved merely by considering possible, hypothetical worlds, not real ones.

Consideration of other worlds immediately posed the problem of what might lie between them. Prior to 1277 the possibility that a vacuum might intervene was rejected because Aristotle had demonstrated the impossibility of void space within and beyond our unique world. In light of article 34 of the condemnation of 1277, however, Nicole Oresme and others now boldly proclaimed the existence of intercosmic void space. Indeed, the necessity of conceding the existence of void space beyond our world—and therefore the possibility that void space could intervene between our world and other possible worlds—could be directly inferred from another article (no. 49), which made it mandatory to concede that God could, if He wished, move the last heaven, or the world itself, with a rectilinear motion even if a vacuum were left behind.[25]

A few fourteenth-century Scholastics moved beyond the merely hypothetical and boldly proclaimed the real existence of an infinite, extracosmic void space, which they identified with God's immensity. Late medieval Scholastics introduced God into space in a more explicit manner than that suggested by the vague metaphors found in earlier patristic, cabalistic, and hermetic traditions.[26] In the fourteenth century Thomas Bradwardine, Jean de Ripa, and Nicole Oresme proclaimed the existence of a real, extracosmic, infinite void space filled by an omnipresent deity. Oresme explicitly identified infinite, indivisible space with God's immensity. These ideas were developed further by Scholastic authors of the sixteenth and seventeenth centuries. The medieval Scholastic idea that God must bear an intimate relationship to space remained a viable concept well into the eighteenth century and played a role in the scientific and theological thought of Isaac Newton himself. From the assumption that infinite space is God's immensity, Scholastics derived most of the same properties for space that non-Scholastics did subsequently. As God's immensity, space was necessarily assigned divine properties, such as homogeneity, immutability, infinity, lack of extension, and the capacity to coexist with bodies to which it offered no resistance. Except for extension, the divinization of space in Scholastic thought produced virtually all the properties that would be attributed to space during the course of the Scientific Revolution.[27]

Although no articles of the Condemnation concerned vacua within the cosmos, it followed inexorably that if God could create a vacuum beyond our world and between possible worlds, He could surely create one or more within our world. Throughout the fourteenth century and later, God was frequently imagined to annihilate all or part of the matter within the material plenum of our world.[28] After 1277 all sorts of situations were hypothesized within such wholly or partially empty spaces. The questions raised became an integral part of a large literature on the nature of vacuum and the imagined behavior of bodies therein. Would the surrounding celestial spheres collapse inward instantaneously as nature sought to prevent formation of the abhorred vacuum? Indeed, could an utterly empty interval, or nothingness, be a vacuum or space? Would a stone placed in such a void be capable of rectilinear motion? Would people placed in such vacua see and hear each other? Analyses of these and similar "thought experiments" in the late Middle Ages were often made in terms of Aristotelian principles even though the conditions imagined were "contrary to fact" and impossible within Aristotelian natural philosophy. From such analyses intelligible and plausible alternatives to Aristotelian physics and cosmology emerged and demonstrated that things could be otherwise than was dreamt of in Aristotle's philosophy.

But if the Condemnation of 1277 beneficially stimulated speculation outside the bounds of Aristotelian natural philosophy, it may also have adversely affected scientific development. In emphasizing God's inscrutable will and his absolute power to do as He pleased, the conservative theologians encouraged a philosophical trend in which confidence in demonstrative certainty, and ultimately confidence in the ability of science to acquire certain truth about the physical world, was weakened. The imaginary physical conditions that were frequently conjured up in the Middle Ages were usually contrary to the "common course of nature" (*communis cursus nature*), which represented the operation of nature interpreted in accordance with Aristotelian natural philosophy. But, it was asked, if God could intervene at will in the causal order, how could scientific principles and laws be absolute, so as to guarantee a "common course of nature"? John Buridan (ca. 1295–ca. 1358), perhaps speaking for many arts masters who wished to defend Aristotelian science as the best means of understanding the physical world, conceded, as he had to, that God could interfere in natural events and alter their course at any time. To alleviate the effect of such uncertainty, however, Buridan urged natural philosophers to proceed as if nature *always* acted with regularity and followed its "common course."[29] On this assumption he believed that "for us the comprehension of truth with certitude is possible."[30] The scientific principles from which these certain truths are derivable are themselves indemonstrable, "but they are accepted because they have been observed to be true in many instances and false in none."[31] Since the ultimate principles depend on experience rather than strict logical demonstration or *a priori* grounds, any of Buridan's certain truths could be overturned by a single empirical counterexample. A degree of uncertainty thus lurked within Buridan's concept of certitude. On methodological grounds Buridan also found a place for the principle of Ockham's razor: that if more than one explanation could "save the phenomena," the simplest should be chosen.

But even if one accepted the simplest explanation as true, how could the best and simplest explanation be determined with certainty? Nicole Oresme (ca. 1320–1382), one of the most brilliant natural philosophers and theologians of the fourteenth century, found experience and human reason inadequate for the proper determination of physical truth. Only faith could furnish us with genuine truth. The fourteenth-century emphasis on God's free and unpredictable will, encapsulated in the concept of God's absolute power, had eroded confidence in human ability to arrive at demonstrated truth in both theology and natural philosophy. In the process of defending God's absolute power to act as He pleased, theologians not only showed the inconclusiveness of certain philosophical proofs traditionally employed to demonstrate what God could or could not do, or to prove his existence or attributes, but they also revealed the limitations of natural philosophy by demonstrating the radically contingent nature of the world. Led by William of Ockham (ca. 1285–1349), many theologians concluded that neither reason nor experience could provide certain knowledge of any necessary connection between causes and their alleged effects. Both reason and experience were consequently deemed inadequate to demonstrate fundamental truths about God and his physical creation, both of which were generally perceived as less knowable during the fourteenth century than in the thirteenth. Where demonstrative certainty about nature was the goal of most natural philosophers in the thirteenth century, probable knowledge was the most that was thought attainable by many in the fourteenth century. While the latter were hardly skeptics, their attitude toward nature, when compared with that of thirteenth-century Scholastics, appears to mark a loss of confidence in human ability to acquire certain knowledge—apart from faith and revelation—about the true nature of God and the world. It was within this intellectual environment that a new trend developed in which physical problems were couched in hypothetical form without existential implication. The phrase *secundum imaginationem*, "according to the imagination," was regularly employed to characterize the innumerable hypothetical possibilities that were formulated in both natural philosophy and theology without any regard for physical reality or application to the world. In marked contrast, the key figures in the later Scientific Revolution—Copernicus, Galileo, Kepler, Descartes, and Newton, to name only the greatest—were confident, perhaps naively, that nature's essential structure and operation were knowable. They were thus encouraged to search after nature's true laws of the physical world. With them, hypothetical conditions were but heuristic devices to arrive at physical truth. Things were quite different in the fourteenth century.

THE IMPACT OF SCIENCE ON THEOLOGY

With a diminished confidence in the certainty of theological and scientific claims, theologians of the fourteenth century turned their attention to hypothetical problems posed *secundum imaginationem*. The *Sentences* (*Sententiae*, or opinions) of Peter Lombard (d. ca. 1160), written around 1150, provided a major point of departure for consideration of these problems. Divided into four books devoted, respectively, to God, the Creation, the Incarnation, and the sacraments, the *Sentences* served for some four centuries as the standard text on which all theological students were required to lecture and comment. Although the second book, devoted to the six days of creation, afforded ample opportunity to consider specific scientific topics such as the nature of light, the four elements, the problem of the supracelestial waters, and the order and motion of the celestial spheres and planets, there was an even more direct impact of natural philosophy on theology involving the attempt to define the relationship of God to the world and his creatures. The injection of science, mathematics, and logic into commentaries on Peter Lombard's *Sentences* grew to such proportions that in 1366 the University of Paris decreed that except where necessary those who read the *Sentences* should avoid the introduction of logical or philosophical material into the treatment of the questions.[32] Despite such appeals, however, Scholastic commentators apparently found it "necessary" to introduce such matters frequently and extensively.

That science and mathematics were applied to the exegesis of the creation account in medieval commentaries on the second book of Peter Lombard's *Sentences* comes as no surprise. Since later antiquity, science and mathematics had been used extensively in hexaemeral commentaries on Genesis—for example, by Saints Basil, Ambrose, and Augustine—a practice that continued throughout the Middle Ages (and well into the seventeenth century) and reached enormous proportions in the lengthy (over a million words) popular, encyclopedic commentary of Henry of Langenstein (composed between 1385 and 1393), which employed almost every scientific subject in its biblical exegesis and made apparent the ease with which science could be introduced into the analysis of creation.[33] During the late Middle Ages, however, science and mathematics were also applied extensively to theological problems that were largely or wholly unrelated to the creation account in Genesis. Themes, techniques, and ideas from natural philosophy and mathematics were frequently used in problems that concerned God's omnipresence, omnipotence, and infinity, as well as his relations to the beings of his own creation and to comparisons between created species. Mathematical concepts were regularly drawn from proportionality theory, the nature of the mathematical continuum, convergent and divergent infinite series, the infinitely large and small, potential and actual infinites, and limits, which included boundary conditions involving first and last instants or points.[34]

Not only were these concepts applied to theological problems, but the latter were frequently formulated in the language of mathematics and measurement. Such concepts were employed to describe the manner in which spiritual entities could vary in intensity and how such variations could best be represented mathematically by application of the peculiarly medieval doctrine known as "the intension and remis-

sion of forms or qualities" (or occasionally as "the configuration of qualities"); they were also to determine the manner in which upper and lower limits, or first and last instants, could be assigned to various processes and events, as in problems concerning free will, merit, and sin. In the fourteenth century Robert Holkot conceived a dilemma requiring *either* that limits be placed on free will *or* that we concede that God might not always be able to reward a meritorious person and punish one who was sinful.[35] Thus he imagined a situation in which a man is alternately meritorious and sinful during the final hour of his life: he is meritorious in the first proportional part of that last hour and sinful in the second proportional part; he is again meritorious in the third proportional part and again sinful in the fourth proportional part, and so on through the infinite series of decreasing proportional parts up to the instant of his death. Since the instant of death cannot form part of the infinite series of decreasing proportional parts of the man's last hour of life, it follows that there is no last instant of his life and, therefore, no last instant in which he could be either meritorious or sinful. As a result, God does not know whether to reward or punish him in the afterlife, which was an unacceptable consequence of the doctrine of free will.[36] One could only conclude that free will cannot be assumed to extend to every imaginable sequence and pattern of choices, a point that Holkot buttressed with eight more continuum arguments.

The mathematical concepts already mentioned, and others as well, were applied to many other problems, especially those concerned with infinites. In this category were included speculations about God's infinite attributes (namely his power, presence, and essence); the kinds of infinites He could possibly create; the infinite distances that separated Him from his creatures, a problem related to the widely discussed concept of the perfection of species;[37] the possible eternity of the world; whether God could improve upon something He had already made, especially whether He could make endlessly better and better successive worlds or whether He could create an ultimate, best possible world.[38] A host of problems was concerned with the behavior of angels, namely how, if at all, an angel could occupy a place; whether it could be in two places simultaneously; whether two or more angels could occupy one and the same place simultaneously; whether angels moved between two separate places with finite or instantaneous speed. In all these problems about angels, basic concepts that had been developed in discussions of the motion of material bodies were applied directly or used as the standard of comparison. The motion of angels was one of the most popular contexts for the intense medieval debate about the nature of the continuum: whether it consisted of parts that are infinitely divisible or was composed of indivisible, mathematical atoms that could be either finite or infinite in number.[39] In contemplating the range of theological topics to which mathematics and mathematical concepts were applied, one may reasonably conclude that in the fourteenth century theology had been quantified.

Further examples of the quantification of theology could easily be supplied, since the process was ubiquitous in *Sentence Commentaries*. But just as the influence of theology, with its emphasis on God's absolute power, had encouraged, and even facilitated, the formulation in natural philosophy of hypothetical speculations about natural impossibilities, so also did the importation into theology of concepts, ideas, and techniques from mathematics and natural philosophy influence and encourage theology to express many of its problems in a scientific and logicomathematical format that was essentially hypothetical and speculative, or, as would be said in the Middle Ages, *secundum imaginationem*. Why theological arguments should have been expressed hypothetically in a logicomathematical format is by no means obvious. The hypothetical character of the arguments is probably attributable to the Condemnation of 1277 and its long aftermath. Either because it was the safer course to pursue or perhaps because of the widespread conviction among theologians that God's nature and the motives for his actions were not directly knowable by human reason and experience, it became rather standard procedure to couch theological problems in hypothetical form. That the format of the problems was frequently quantitative and logicomathematical and involved measurements and comparisons between all sorts of spiritual and incorporeal entities is perhaps also explicable by the educational background of theological students and masters. With their overwhelming emphasis on natural philosophy and logic, and sufficient training in geometry, they may have found it quite natural to formulate, and even recast, their hypothetical theological problems in the quantitative languages that had formed their common educational background and that had been fashioned by natural philosophers in the first thirty or forty years of the fourteenth century.

Whatever the reasons for the hypothetical and quantitative format, it is no exaggeration to detect in all of this a major change in the techniques of theology, the like of which had never been seen before. Under the seductive influence of science, mathematics, and logic, theology found major expression in a quantified format within which solutions to a host of hypothetical theological problems were sought by various kinds of measurements, especially in problems that involved relationships between God and his creatures.[40] Traditional theological questions were often recast in a quantitative mold that allowed the easy application of mathematical and logical analysis. Yet

this massive influx of quantitative apparatus appears to have had little if any impact on the content of theology. But if content was unaffected, the traditional methodology of theology had been transformed by the emphasis on natural philosophy and mathematics. It is this transformation that marks the fourteenth century and the late Middle Ages as an extraordinary period in the history of the relations between science and theology in the Western world.

The impact of science on theology was not all of this kind, however. The application of science to the interpretation of the creation account in Genesis was quite traditional and generally lacked the quantitative and hypothetical, imaginary character that dominated other aspects of theology. Basic procedures for the application of science to the creation account had been laid down by Saint Augustine in his *Commentary on Genesis*[41] and were faithfully summarized by Saint Thomas Aquinas (ca. 1225–1274) in the latter's own commentary on the six days of creation in the *Summa theologiae*. In considering whether the firmament was made on the second day, Aquinas observes that Augustine had insisted upon two hermeneutical points in the explication of scriptural texts:

> First, the truth of Scripture must be held inviolable. Secondly, when there are different ways of explaining a Scriptural text, no particular explanation should be held so rigidly that, if convincing arguments show it to be false, anyone dare to insist that it still is the definitive sense of the text. Otherwise unbelievers will scorn Sacred Scripture, and the way to faith will be closed to them.[42]

These two vital points constituted the basic medieval guidelines for the application of a continually changing body of scientific theory and observational data to the interpretation of physical phenomena described in the Bible, especially the creation account. The scriptural text must be assumed true. When God "made a firmament, and divided the waters that were under the firmament, from those that were above the firmament,"[43] one could not doubt that waters of some kind must be above the firmament.[44] The nature of that firmament and of the waters above it were, however, inevitably dependent on interpretations that were usually derived from contemporary science. It is here that Augustine and Aquinas cautioned against a rigid adherence to any one interpretation lest it be shown subsequently untenable and thus prove detrimental to the faith.

In conformity with his own admonitions Aquinas adopted no single interpretation of either "firmament" or the "waters" above the firmament. Instead he enumerated different historical interpretations that were compatible with Scripture and patiently explained how the application of different scientific theories implied different and sometimes conflicting consequences. The firmament created on the second day was susceptible of two interpretations: it could be the sphere of the fixed stars or part of the atmosphere where clouds condense.[45] The first of these opinions could be interpreted in a variety of ways, each dependent on the material nature assigned to the firmament, that is, whether it was compounded of the four elements (Empedocles), or of a single element such as fire (Plato), or indeed consisted of a fifth element wholly different from the other four (Aristotle). For each of these possibilities Aquinas explained in what sense it was or was not compatible with the creation of a firmament on the second day.

Aquinas approached the meaning of the "waters" above the firmament in a similar manner. Each of a variety of possible significations was made to depend on the material nature attributed to the firmament.[46] Thus if the sphere of the fixed stars is the firmament and is composed of the four elements, the waters above the firmament could then plausibly be interpreted as the ordinary element water, but if the firmament is not compounded of the four regular elements, the waters above the firmament must be something other than the regular element water. In the latter event, "water" may be interpreted in the Augustinian manner as the unformed matter of which bodies are made. Its designation as aqueous may even derive from its transparent nature rather than its fluidity. After all, those waters may be solid like ice, that is crystalline, as in the "crystalline heaven of some authors."[47] Should the firmament be construed as that part of the atmosphere where clouds are formed, the waters above the firmament would be identical with those that are evaporated below and rise up to fall as rain. Because of the solidity of the celestial spheres these evaporated waters could not rise beyond the moon and *a fortiori* would never rise above the celestial region itself. Indeed, they could not even survive the heat of the fiery region immediately below the moon and would never reach the celestial spheres. With the presentation of these differing opinions Aquinas felt he had accomplished his objective. Because they were all compatible with the scriptural text, he saw no need—and indeed no way—to choose among them.

Occasionally the literal meaning of scriptural statements conflicted directly with universally accepted scientific theories and observations. In such instances the scriptural text had to be reinterpreted, as in the case of Psalms 103:2, where God is said to have stretched out the firmament like a tent. Because of the near unanimous opinion that the earth is spherical, it was necessary that the firmament also be spherical, a condition that a tent could not fulfill. Under these circumstances Augustine and medieval Scholastics generally agreed that it was the biblical exegete's duty to demonstrate that the description of the firmament as a tent was not contrary to the scientific truth of a spherical firmament.[48] Augustine admonished against the development of a special Christian science that would attempt to explain the literal meaning of difficult texts that conflicted with well-founded scientific truths. Such attempts would undermine the credibility of Christianity. Augustine's attitude was thus compatible with both literal and allegorical interpretations of Scripture. The literal meaning of a text was always preferable, even where multiple interpretations were unavoidable, as with the supracelestial waters. But wherever a scriptural passage conflicted with a scientifically demonstrated proposition—as happened in Psalms 103:2—the scientific interpretation must prevail to prevent any erosion of confidence in scriptural truth. Under such circumstances, an allegorical interpretation was required so that truth and Scripture would be in harmony.

During the late Middle Ages broad and liberal, rather than narrow and literal, interpretations were the rule in biblical exegesis involving physical phenomena. An important illustration of this tendency is the famous passage that describes God's miraculous intervention on behalf of the army of Joshua (Joshua 10:12–14). By commanding the sun to stand still over Gibeon, God lengthened the day and allowed Israel to triumph over the Amorites. Since it was the sun—not the earth—that was ordered to come to rest, it followed that night and day were the consequence of the sun's daily revolution around an immobile earth rather than a result of the earth's daily rotation around its own axis. Here the Bible was in conformity with the best of Greek and medieval astronomy. Yet Nicole Oresme challenged this seemingly routine interpretation. "When God performs a miracle," he explained,

> we must assume and maintain that He does so without altering the common course of nature, in so far as possible. Therefore, if we can save appearances by taking for granted that God lengthened the day in Joshua's time by stopping the movement of the earth or merely that of the region here below—which is so very small and like a mere dot compared to the heavens—and by maintaining that nothing in the whole universe—and especially the huge heavenly bodies—except this little point was put off its ordinary course and regular schedule, then this would be a much more reasonable assumption.[49]

Despite the plain statement of Scripture that the sun stopped in its course, Oresme argued that the same effect could be produced more economically and with less interruption of the common and regular course of nature by the assumption of a *real* daily axial motion for the much smaller earth. The sun's cessation of motion could thus be construed as only apparent and not real, an appearance produced when God caused the real axial rotation of the earth to cease. On the assumption that God always acted in the simplest and least disruptive manner, He surely would have stopped the smaller earth and not the sun, from which it followed that the apparent daily motion of the sun results from a real rotation of the earth. But Scripture plainly states that the sun, not the earth, stood still. Oresme's assumption would conflict not only with this clear biblical statement but with many others that also speak of the sun's motion or the earth's immobility.[50] Such passages, Oresme countered, may not reflect literal truth but merely conform "to the customary usage of popular speech just as it [that is, Holy Scripture] does in many other places, for instance, in those where it is written that God repented, and He became angry and became pacified, and other such expressions which are not to be taken literally."[51]

However, despite persuasive arguments in favor of the earth's axial rotation, Oresme knew that it was beyond his powers to demonstrate it scientifically. In the end, faithful to the admonitions of Augustine and Aquinas, he retained the literal meaning of the Bible and rejected the earth's rotation. Although he adopted the traditional opinion, Oresme's interpretation of the Joshua passage was more daring than Galileo's in 1615. As a confirmed Copernican, Galileo interpreted the Joshua text literally. With the sun at the center of the planetary system, Galileo assumed that it controlled the motions of all the planets. Hence

> when God willed that at Joshua's command the whole system of the world should rest and should remain for many hours in the same state, it sufficed to make the sun stand still. Upon its stopping, all the other revolutions ceased. . . . And in this manner, by the stopping of the sun, without altering or in the least disturbing the other aspects and mutual positions of the stars, the day could be lengthened on earth—which agrees exquisitely with the literal sense of the sacred text.[52]

Oresme's interpretation was radically different and far more striking because it was contrary to the literal meaning of the text, which, in this instance, agreed fully with Aristotelian cosmology and Ptolemaic astronomy. Since Oresme's consideration of the earth's diurnal rotation was in the end merely hypothetical, it caused no apparent theological consternation. Whether the same indifference would have prevailed if Oresme had concluded in favor of the reality of the earth's daily axial rotation is simply unanswerable, as is the question whether he might have suffered a fate similar to that which befell Galileo some 250 years later.

We may reasonably conclude that the application of science to medieval scriptural exegesis was effected without noticeable constraints or interference. Indeed, the text of Holy Scripture was more often compelled to conform to the established truths of science than vice versa. The application of science to Scripture is perhaps best characterized by flexibility. Though the literal meaning was preferred, provision was made for allegorical interpretations. Potential conflict lurked, however, in passages where the literal meaning contradicted what were thought to be scientifically demonstrated truths. While theologians found it easy to place an allegorical interpretation on the passage in Psalms 103:2—no one believed that the firmament was shaped like a tent—they would eventually prove unyielding, as Galileo would learn to his sorrow, on the many passages that mentioned the sun's motion and the earth's immobility. Galileo's insistence on an allegorical interpretation of those passages, on the grounds that he could scientifically demonstrate the earth's motion, clashed with the interpretation of the theologians who rejected his demonstrations and insisted on the traditional, literal sense. Ironically, to legitimate their positions both sides quite properly appealed to Augustine's conception of scriptural interpretation. During the Middle Ages no similar conflict erupted, not even on the always vexing problem of the eternity of the world. The medieval theologian–natural philosopher was generally free to propose and adopt a single interpretation—though encouraged not to embrace it unreservedly if it were not scientifically demonstrated—or to enunciate multiple interpretations without firm commitment to any one of them.

DID THEOLOGY INHIBIT SCIENTIFIC INQUIRY?

We must finally confront an unavoidable question on the relations of medieval science and theology: how, if at all, did the latter affect the freedom of inquiry of the former? The attempts to ban and expurgate the physical works of Aristotle during the first half of the thirteenth century bear witness to theological fears about the potential power of uncontrolled philosophical learning. The Condemnation of 1277 marked the culmination of theological efforts to contain and control natural philosophy. The bishop of Paris and his theological colleagues sought to restrict, under penalty of excommunication, categorical claims for a number of ideas in natural philosophy. It was now forbidden, for example, to deny creation and assert the eternity of the world, to deny the possibility of other worlds, and to deny that God could create an accident without a subject in which to inhere. Although these restrictions fell equally on masters of arts and theologians at the University of Paris, the arts masters were more seriously affected than their theological colleagues. Not only were they obliged to comply with the Condemnation of 1277, but, in the absence of professional credentials in theology, they had been required, since 1272, to swear an oath that they would avoid disputation of purely theological questions and were generally discouraged from introducing theological matters into natural philosophy.[53]

Despite such restrictions, however, arts masters were free to uphold almost all of Aristotle's scientific conclusions and principles, provided that they conceded to God the power to create events and phenomena that were contrary to those conclusions and principles and which were therefore naturally impossible in the Aristotelian system. They were thus free to support Aristotle and deny the existence of other worlds if only they would allow that God could create them if He wished. Even the eternity of the world, which was to the relations between science and religion in the Middle Ages what the Copernican theory was to the sixteenth and seventeenth centuries and what the Darwinian theory of evolution was to the nineteenth and twentieth centuries, could be proclaimed hypothetically when "speaking naturally" (*loquendo naturaliter*), that is, when considering a question in natural philosophy. Indeed, on the assumption that there was a fixed quantity of matter in the world and that the world was eternal, Albert of Saxony concluded in the fourteenth century that over an infinite time this limited quantity of matter would, of necessity, furnish the bodies for an infinite number of human forms. It followed that on the day of resurrection, when every soul receives its material body, the same finite quantity of matter would be received by an infinite number of human souls, a clearly heretical consequence, since one and the same body would have to receive a plurality of souls. To this dilemma Albert's response was typical for natural philosophers who regularly contended with theological restrictions: "The natural philosopher is not much concerned with this argument because when he assumes the eternity of the world, he denies the resurrection of the dead."[54] By such appeals to the hypothetical, medieval natural philosophers could consider almost any condemned and controversial proposition. Nevertheless, they were not permitted to proclaim such beliefs categorically, and to the extent that their discussions touched theology or had theological implications, they were inhibited and frustrated, as when John Buridan complained that in his analysis of the vacuum, which touched upon faith and theology, he was reproached by the theological masters for intermingling theological matters.[55]

With the arts masters forbidden to apply their knowledge to theology, we are left with the theologians as the class of scholars who applied science to theology and theology to science during the Middle Ages. Not only were they thoroughly trained in natural philosophy and theology, but some were also significant contributors to science and mathematics, as the names of Albertus Magnus, John Pecham, Theodoric of Freiberg, Thomas Bradwardine, Nicole Oresme, and Henry of Langenstein testify. Because they were trained in both natural philosophy and theology, medieval theologians were able to interrelate science and theology with relative ease and confidence, whether this involved the application of science to scriptural exegesis, the application of God's absolute power to alternative possibilities in the natural world, or even the frequent invocation of scriptural texts in scientific treatises in support of scientific theories and ideas. Theologians had a remarkable degree of intellectual freedom[56] and, for the most part, did not allow their theology to hinder or obstruct inquiry into the structure and operation of the physical world. If there was any real temptation to produce a "Christian science," they successfully resisted it. Biblical texts were not employed to "demonstrate" scientific truths by blind appeal to divine authority. When Nicole Oresme inserted some fifty citations to twenty-three different books of the Bible in his scientific treatise *On the Configurations of Qualities and Motions*, he did so only by way of example or for additional support, but in no sense to demonstrate an argument.[57]

Ironically, rather than inhibiting scientific discussion, theologians may have inadvertently produced the opposite effect, as suggested by the impact of the doctrine of God's absolute power described above. Theological restrictions embodied in the Condemnation of 1277 may have actually prompted consideration of plausible and implausible alternatives and possibilities far beyond what Aristotelian natural philosophers might otherwise have considered, if left to their own devices. While these speculations did not lead to the abandonment of the Aristotelian worldview, they generated some of the most daring and exciting scientific discussions of the Middle Ages.

That medieval theologians combined extensive and intensive training in both natural philosophy and theology, and possessed exclusive rights to interrelate the two, may provide a key to explain the absence of a science-theology conflict in the extensive medieval commentary literature on the *Sentences* and Scripture. For the host of issues they regularly confronted, the medieval theologian–natural philosophers knew how to subordinate the one discipline to the other and to avoid conflict and confrontation. Indeed, they were in an excellent position to harmonize the two disciplines while simultaneously pursuing all manner of hypothetical and contrary-to-fact conditions and possibilities. Compared to the situation in late antiquity, when Christianity was struggling for survival, and the difficult times that lay ahead, the late Middle Ages—except for the 1260s and 1270s—was a relatively tranquil period in the long interrelationship between science and theology.

NOTES

1. Although there are significant differences between the modern term *science* and the medieval term *natural philosophy,* the two will be used here interchangeably. In practical terms, natural philosophy (or "natural science," as it was occasionally called) was generally identified with Aristotle's "natural books" (*libri naturales*), which treated themes in cosmology, physics, and matter theory. As one of the three major subdivisions of speculative philosophy, natural philosophy was concerned exclusively with mobile bodies and their changes. Although natural philosophy was distinct from mathematics, sciences that used mathematics, such as optics and astronomy, but were also concerned with mobile bodies could also fall under the consideration of natural philosophy. For the place of natural philosophy in the medieval division of the sciences see Robert Kilwardby, O.P., *De Ortu Scientiarum,* ed. Albert G. Judy, O.P. (Toronto: British Academy and the Pontifical Institute of Mediaeval Studies, 1976), pp. 15–29, and Domingo Gundisalvo, *On the Division of Philosophy,* partially translated by M. Clagett and E. Grant in *A Source Book in Medieval Science,* ed. Edward Grant (Cambridge, Mass.: Harvard Univ. Press, 1974), pp. 62–65.

2. See Sister Emma Therese Healy, ed and trans., *Saint Bonaventure's "De reductione artium ad theologiam": A Commentary with an Introduction and Translation* (Saint Bonaventure, N.Y.: The Franciscan Institute, 1955), p. 41. I have added the bracketed word. For the manner in which Roger Bacon subordinated mathematics to theology see David C. Lindberg, "On the Applicability of Mathematics to Nature: Roger Bacon and His Predecessors," *British Journal for the History of Science* 15 (1982): 3–26. The most frequently cited biblical passages in support of the handmaiden idea were Exodus 3:22 and 12:36, which spoke of despoiling the Egyptians of their treasures. In 1231, when he sought to justify the expurgation of Aristotle's physical treatises, Pope Gregory IX referred to the despoiling of the Egyptians by the Hebrews (for the passage see *Source Book,* ed. Grant, p. 43).

3. André Cantin, *Les sciences séculières et la foi: Les deux voies de la science au jugement de S. Pierre Damien (1007–1072)* (Spoleto: Centro Italiano di Studi sull'Alto Medioevo, 1975), pp. 557, 578.

4. Ibid., p. 580.

5. Ibid., pp. 536 ff.

6. From Honorius's *Elucidarium* 1.12 as translated by M. D. Chenu, O.P., *Nature, Man, and Society in the Twelfth Century: Essays on New Theological Perspectives in the Latin West,* preface by Etienne Gilson, ed. and trans. Jerome Taylor and Lester K. Little (Chicago: Univ. of Chicago Press, 1968; original French version published in 1957), p. 8 n. 15.

7. See Tina Stiefel, "The Heresy of Science: A Twelfth-Century Conceptual Revolution," *Isis* 68 (1977): 350.

8. From William's *Philosophia mundi* 1.23 as translated in Chenu, *Nature, Man, and Society,* p. 11. For William's attitude toward the relationship between physical law and the exegetical tradition on Genesis see Helen R. Lemay, "Science and Theology at Chartres: The Case of the Supracelestial Waters," *British Journal for the History of Science* 10 (1977): 229–233.

9. Chenu, *Nature, Man and Society,* p. 12.

10. The bans of 1210 and 1215 were issued by the provincial synod of Sens, which included the bishop of Paris. The order to expurgate the books of Aristotle in 1231 came from Pope Gregory IX, who appointed a three-member committee for the purpose. Whatever the reasons, the committee never carried out its assignment. For a translation of the documents of 1210 and 1231 see *Source Book,* ed. Grant, pp. 42–43.

11. For the document of 1255 see *Source Book,* ed. Grant, pp. 43–44.

12. The different reactions to pagan philosophy are described by John Wippel, "The Condemnations of 1270 and 1277 at Paris," *Journal of Medieval and Renaissance Studies* 7 (1977): 195.

13. See Frederick Copleston, S.J., *A History of Philosophy,* 9 vols. (Westminster, Md.: Newman Press, 1946–1975), 2:318–319.

14. Ibid., p. 319. Edith Sylla observes ("Autonomous and Handmaiden Science: St. Thomas Aquinas and William of Ockham on the Physics of the Eucharist," in *The Cultural Context of Medieval Learning,* ed. John E. Murdoch and Edith D. Sylla [Dordrecht and Boston: D. Reidel, 1979], pp. 354, 363) that despite Aquinas's acknowledgment of the autonomy of philosophy (which includes natural philosophy) from theology, he often subordinated the former to the latter, as exemplified in his discussion of the Eucharist. By contrast, William of Ockham (ca. 1285–1349) refused to bend physics and natural philosophy to the needs of theology, choosing rather to explain physically inexplicable religious phenomena by God's direct intervention.

15. Wippel, "Condemnations of 1270 and 1277," p. 175.

16. For some of these warnings see Leo Elders, S.V.D., *Faith and Science: An Introduction to St. Thomas' "Expositio in Boethii De Trinitate"* (Rome: Herder, 1974), p. 51 and nn. 42, 43.

17. The Latin text of the 219 articles, in their original order, appears in Heinrich Denifle and Emile Chatelain, *Chartularium Universitatis Parisiensis,* 4 vols. (Paris: Ex typis Fratrum Delalain, 1889–1897), 1:543–555; for a methodical regrouping of the articles aimed at facilitating their use see Pierre F. Mandonnet, O.P., *Siger de Brabant et l'Averroïsme latin au XIII*me *siècle, II*me *partie: Textes inédits,* 2d ed. (Louvain: Institut supérieur de philosophie de l'Uni-

versité, 1908), pp. 175–191. Using Mandonnet's reorganized version, Ernest L. Fortin and Peter D. O'Neill translated the articles into English in *Medieval Political Philosophy: A Sourcebook*, ed. Ralph Lerner and Muhsin Mahdi (New York: Free Press of Glencoe, 1963), pp. 337–354. Their translation was reprinted in *Philosophy in the Middle Ages: The Christian, Islamic, and Jewish Traditions*, ed. Arthur Hyman and James J. Walsh (Indianapolis: Hackett Publishing Co., 1973), pp. 540–549. Selected articles relevant to science have been translated in *Source Book*, ed. Grant, pp. 45–50. For a discussion of each article, including its sources, see Roland Hisette, *Enquête sur les 219 articles condamnés à Paris le 7 mars 1277*, Philosophes médiévaux, vol. 22 (Louvain: Publications Universitaires; Paris: Vander-Oyez, 1977).

18. Wippel, "Condemnations of 1270 and 1277," p. 186.

19. Here and in what follows on the Condemnation of 1277 I follow my article "The Condemnation of 1277, God's Absolute Power, and Physical Thought in the Late Middle Ages," *Viator*, 10 (1979): 211–244. For the distinction between God's absolute power and his ordained power (*potentia ordinata*) see p. 215.

20. *Source Book*, ed. Grant. p. 49.

21. Articles 152, 153, and 154 as translated in *Source Book*, ed. Grant, p. 50.

22. Article 40 as translated in Wippel, "Condemnations of 1270 and 1277," p. 187.

23. It had already been proclaimed by Saint Peter Damian in the eleventh century (for a translation of the relevant sections from Damian's *On Divine Ominipotence [De divina omnipotentia]* see *Medieval Philosophy from St. Augustine to Nicholas of Cusa*, ed. John F. Wippel and Allan Wolter, O.F.M. [New York: The Free Press, 1969], pp. 143–152, esp. 148–149) and by Peter Lombard in the twelfth century (the passage from Peter's *Sentences* is translated in Grant, "Condemnation of 1277," p. 214 n. 10).

24. For the references and further discussion see Grant, "Condemnation of 1277," pp. 220–223.

25. A detailed discussion appears in ibid., pp. 226–232.

26. By "hermetic" tradition is meant the approximately fifteen anonymous Greek treatises written sometime between A.D. 100 and 300 and ascribed to the Egyptian god Hermes Trismegistus ("Thrice-Great Hermes"). A diverse collection of mystical and spiritual works that incorporated popular Greek philosophy along with Jewish and Persian elements, the hermetic treatises exercised some influence during the Middle Ages but had their greatest impact during the Renaissance. For an account of their significant role in Western thought see Frances A. Yates, *Giordano Bruno and the Hermetic Tradition* (Chicago: Univ. of Chicago Press, 1964).

27. The summary presented here of the relations between God and space is drawn from my book, *Much Ado about Nothing: Theories of Space and Vacuum from the Middle Ages to the Scientific Revolution* (Cambridge: Cambridge Univ. Press, 1981), esp. pp. 260–264.

28. See Grant, "Condemnation of 1277," pp. 240–241.

29. Ockham had also adopted this attitude (see Sylla, "Autonomous and Handmaiden Science," p. 359), as did others who sought to assign meaning and significance to the "common course of nature."

30. Buridan, *Questions on the Metaphysics*, bk. 2, question 1. The interpretations of Buridan and Oresme (below) are based on my article "Scientific Thought in Fourteenth-Century Paris: Jean Buridan and Nicole Oresme," in *Machaut's World: Science and Art in the Fourteenth Century*, ed. Madeleine Pelner Cosman and Bruce Chandler, Annals of the New York Academy of Sciences, vol. 314 (New York: New York Academy of Sciences, 1978), pp. 105–124, esp. p. 109. On the quotation from Buridan see also William A. Wallace, *Prelude to Galileo: Essays on Medieval and Sixteenth-Century Sources of Galileo's Thought* (Dordrecht and Boston: D. Reidel, 1981), p. 345.

31. From Buridan's *Questions on the Metaphysics*, bk. 2, question 2, as translated by Ernest A. Moody, "Buridan, Jean," *Dictionary of Scientific Biography* 2:605.

32. Denifle and Chatelain, *Chartularium Universitatis Parisiensis*, 3:144. The statute is cited and discussed by John E. Murdoch, "From Social into Intellectual Factors: An Aspect of the Unitary Character of Late Medieval Learning," in *Cultural Context*, ed. Murdoch and Sylla, p. 276. Some 160 years later, John Major (1469–1550), in the introduction to the second book of his *Sentence Commentary* (1528), declared that "for some two centuries now, theologians have not feared to work into their writings questions which are purely physical, metaphysical, and sometimes purely mathematical" (translated by Walter Ong, *Ramus, Method, and the Decay of Dialogue: From the Art of Discourse to the Art of Reason* [Cambridge, Mass.: Harvard Univ. Press, 1958], p. 144).

33. Henry's *Lecturae super Genesim*, to use its Latin title, has been analyzed by Nicholas Steneck, *Science and Creation in the Middle Ages: Henry of Langenstein (d. 1397) on Genesis* (Notre Dame, Ind.: Univ. of Notre Dame Press, 1976); see esp. p. 21.

34. The basic research on the application of concepts of mathematics and measurement to theology has been done by John E. Murdoch in at least two articles on which I have relied: "*Mathesis in Philosophiam Scholasticam Introducta:* The Rise and Development of the Application of Mathematics in Fourteenth Century Philosophy and Theology," in *Arts libéraux et philosophie au Moyen Âge: Actes du quatrième Congrès international de philosophie médiévale, Université de Montréal, 27 août–2 septembre 1967* (Montreal: Institut d'études médiévales; Paris: J. Vrin, 1969), pp. 215–254; and "From Social into Intellectual Factors," pp. 271–339.

35. The following illustration appears in Holkot's (or Holcot's) *Sentence Commentary*, bk. 1, question 3, the Latin text of which is quoted by Murdoch ("From Social into Intellectual Factors," p. 327 n. 102) from the edition of Lyon, 1518. For the interpretation of this difficult argument I am indebted to my student Mr. Peter Lang.

36. Ockham argued that if God wished, He could save a man who died without grace (see Sylla, "Autonomous and Handmaiden Science," p. 358).

With respect to Holkot's argument, Ockham might have replied that God could save the man regardless of his state of grace at the final moment of life and despite God's ignorance of that state. The startling aspect of Holkot's argument, however, is that God could be in ignorance about a person's state of grace or sin at the last moment of life.

37. On the application of scales and measurements to the perfection of species see Murdoch, *"Mathesis in Philosophiam Scholasticam Introducta,"* pp. 238–239.

38. See Steven J. Dick, *Plurality of Worlds: The Origins of the Extraterrestrial Life Debate from Democritus to Kant* (Cambridge: Cambridge Univ. Press, 1982), pp. 31–35; and Armand Maurer, "Ockham on the Possibility of a Better World," *Mediaeval Studies* 38 (1976): 291–312.

39. Murdoch, *"Mathesis in Philosophiam Scholasticam Introducta,"* p. 217 n. 4.

40. Murdoch, "From Social into Intellectual Factors," p. 292.

41. *De Genesi ad litteram* 1.18, 19, and 21. These passages are partly translated and partly summarized by Stanley L. Jaki, *Science and Creation: From Eternal Cycles to an Oscillating Universe* (New York: Science History Publications, 1974), pp. 182–183.

42. Saint Thomas Aquinas, *Summa theologiae: Latin Text and English Translation, Introductions, Notes, Appendices and Glossaries*, vol. 10, *Cosmogony* (1a65–74), trans. William A. Wallace, O.P. (New York and London: Blackfriars in conjunction with McGraw-Hill Book Co. and Eyre & Spottiswoode, 1967), part 1, question 68, 1 (the second day), pp. 71–73.

43. Genesis 1:7 (Douay-Rheims translation).

44. An opinion expressed by Saint Augustine, *De Genesi ad litteram*, 2.5, and quoted approvingly by Aquinas, *Summa theologiae* (trans. Wallace), part 1, question 68, 2, p. 79.

45. *Summa theologiae* (trans. Wallace), part 1, question 68, 1, pp. 73–75.

46. Aquinas, *Summa*, part 1, question 68, 2, pp. 79–83.

47. Ibid., p. 81.

48. Jaki, *Science and Creation*, pp. 182–183, provides the references to Augustine's *Commentary on Genesis*. Presumably, William of Conches thought he was following Augustine's advice when he insisted upon an allegorical interpretation of "firmament" as air, rather than taking it literally as anything celestial, beyond or above which it was impossible for water of any kind to exist (see Lemay, "Science and Theology at Chartres," pp. 229–231).

49. Nicole Oresme, *Le livre du ciel et du monde*, ed. Albert D. Menut and Alexander J. Denomy, C.S.B., trans. Albert D. Menut (Madison: Univ. of Wisconsin Press, 1968), p. 537. The passage is reprinted in *Source Book*, ed. Grant, p. 509.

50. For example, Genesis 15:12; Ecclesiastes 1:5; 2 Samuel 2:24; Psalms 92:1; Ephesians 4:26; and James 1:11.

51. *Le livre du ciel et du monde*, p. 531; *Source Book*, ed. Grant, p. 507.

52. "Letter to Madame Christina of Lorraine, Grand Duchess of Tuscany, Concerning the Use of Biblical Quotations in Matters of Science," in *Discoveries and Opinions of Galileo*, trans. Stillman Drake (Garden City, N.Y.: Doubleday, 1957), pp. 213–214.

53. For the statute see *Source Book*, ed. Grant, pp. 44–45. On John Buridan's complaint against theological restrictions in his discussion of the vacuum see pp. 50–51.

54. For the text and discussion based on Albert's *Questions on Generation and Corruption* see Anneliese Maier, *Metaphysische Hintergründe der spätscholastischen Naturphilosophie* (Rome: Edizioni di Storia e Letteratura, 1955), pp. 39–40. Maier also notes (p. 41) that, in coping with the same question, Marsilius of Inghen declared that, in truth, the world had a beginning and will come to an end. Whether, on the assumption of the eternity of the world, an infinity of souls would receive the same matter is a theological question and of no concern in a work on natural philosophy. Although he sought to avoid the question, Marsilius did allow that God could, if He wished, assign one matter to many men.

55. For the text of Buridan's complaint see *Source Book*, ed. Grant, pp. 50–51.

56. For an elaborate defense of this claim see Mary Martin McLaughlin, *Intellectual Freedom and Its Limitations in the University of Paris in the Thirteenth and Fourteenth Centuries* (New York: Arno Press, 1977; Ph.D. diss., Columbia University, 1952), chap. 4 ("The Freedom of the Theologian as Scholar and Teacher"), pp. 170–237, and chap. 5 ("Intellectual Freedom and the Role of the Theologian in the Church and in Society"), p. 238.

57. See Marshall Clagett, ed. and trans., *Nicole Oresme and the Medieval Geometry of Qualities and Motions: A Treatise on the Uniformity and Difformity of Intensities Known as "Tractatus de configurationibus qualitatum et motuum"* (Madison: Univ. of Wisconsin Press, 1968), pp. 134–135.