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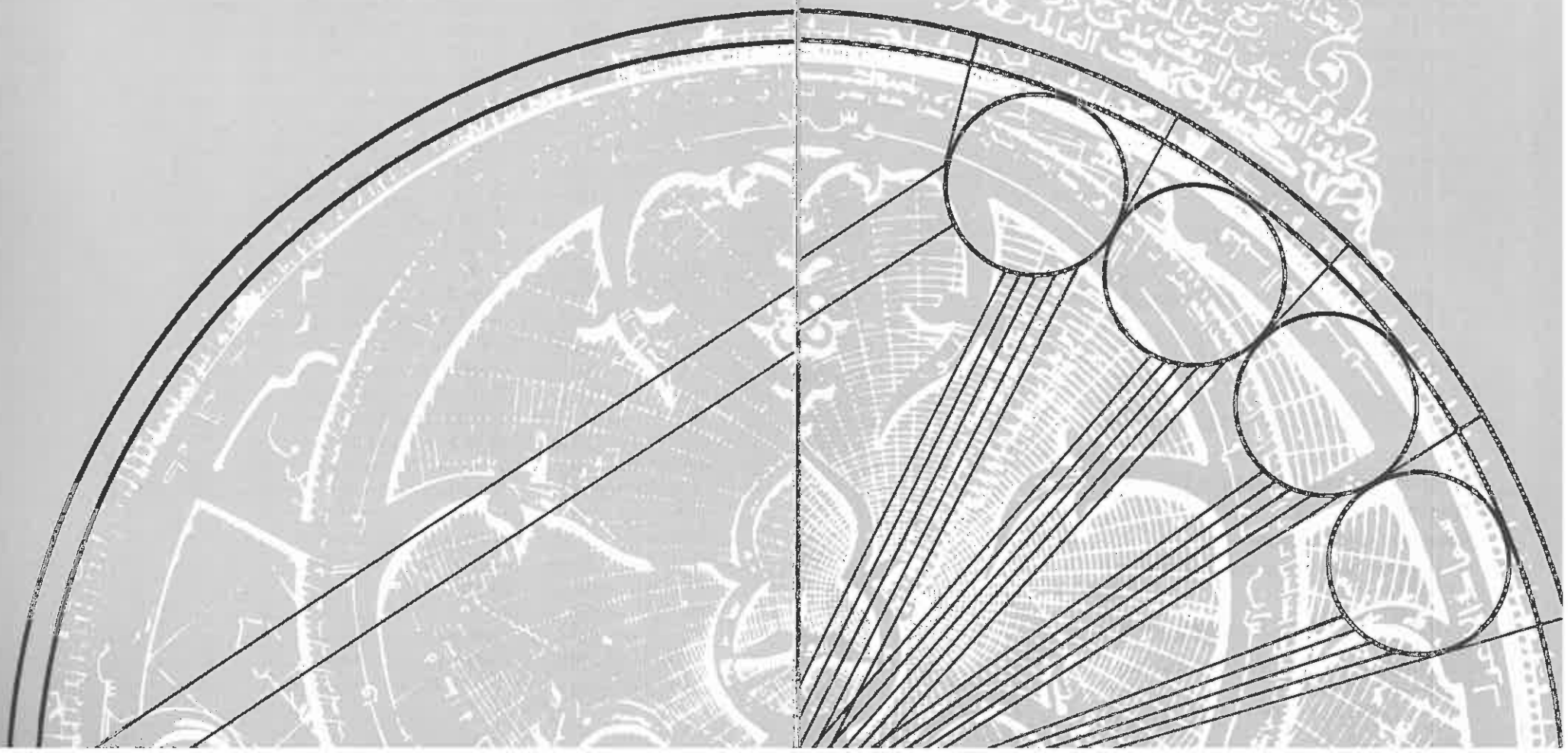

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Pearl Kibre and Nancy G. Siraisi

The Institutional Setting: The Universities

Origins of the Universities

From the close of the twelfth century onward, science found its chief institutional home in the universities or corporate associations of scholars—students or masters (from the Latin term *magister* for teacher).[1] These universities deserve our attention not only as the transmitters of the knowledge of the past but also and more specifically as the nuclei and breeding ground for the creative and dynamic forces that were to coalesce and produce the subsequent scientific achievements of Western culture. Although their exact beginnings are obscure, the universities of scholars were both reminiscent of earlier precepts and characteristic products of the age in which they appeared. Their emergence as autonomous corporate associations in Paris, Oxford, Bologna, Padua, and elsewhere coincided with the formation of guilds in industry and commerce, and of self-governing communes in the civic sphere. The term *university* (*universitas*) itself originally applied to the totality of any group of persons with a common aim or function, such as a craft or merchant guild or a self-governing association of citizens organized as a legal entity with a right to sue or be sued, under precepts derived from Roman law. These self-governing associations, in conformity with contemporary views regarding a guild or sworn brotherhood of men performing a like function or following a common occupation—in this instance, teaching and studying a prescribed curriculum—set their own requirements and steps for the achievement of their specified objectives. In some respects, these progressive stages in the universities of scholars, namely, matriculation, bachelor, and master (one who received the degree or license to teach upon the successful completion of such set intellectual exercises as the disputations, determination or defense of the thesis, and formal inception into the guild of teaching masters), paralleled the steps in a craft guild of apprenticeship, journeyman, and finally master workman, following the completion of a perfect piece of work (a shoe, a chest, or the like).

However, despite their outward resemblance to the craft or merchant guilds, the universities of scholars differed from them in the status of their members. The latter, unlike the members of craft or merchant guilds, were specially privileged, since they were concerned with the acquisition and transmission of knowledge. In recognition of this distinction, scholars had since antiquity, and particularly under precepts of Roman law, been accorded special exemptions and privileges; and these were augmented in the High Middle Ages by Frederick Barbarossa in the *Authentica habita* granted in 1158, and by successive grants of privilege by pontiffs, monarchs, and municipalities. Scholars, indeed, constituted a new privileged class in society, the intellectuals; they were the new nobility, as suggested by contemporary references to the "new chivalry," distinguished from the feudal aristocracy since they boasted no military prowess nor material wealth, although they borrowed feudal terminology and ceremony. The scholar on the first rung of the ladder of the academic hierarchy was named "bachelor," a term originally signifying a squire; and the ceremony attending the bestowal of the degree or license to teach was thought to confer "a sort of intellectual knighthood."[2]

The recipients of this intellectual knighthood, despite their contemporary trappings, were in their preparatory training heirs to a long tradition embodied in the Greco-Roman ensemble of the seven liberal arts, divided into the trivium—grammar, rhetoric, and logic—and the quadrivium—arithmetic, geometry, music, and astronomy. These arts, related to "productive reason," and "ordained to knowledge," were believed to be the indispensable foundation for higher and more specialized learning, and they had been so taught in the imperial and municipal schools of Rome. However, with the collapse of the Roman political structure in the West and the virtual disappearance of the imperial and municipal schools, leaving only a thin stream of lay teaching, the task of transmitting the arts fell to the agencies of the Roman church, under the expressed belief that they and other elements of Greco-Roman thought were essential for a rational understanding of scripture. St. Basil (d. 379), for example, in his *Hexaemeron* (a discussion of the six days of creation) utilized Greek scientific theories on cosmology, light, the four elements, and the four

qualities, as well as the deviant conception of matter as uncreated and eternal, to bridge the gap between pagan thought and Christian doctrine and to elucidate the account of the creation of the physical universe in Genesis. Moreover, as in the words of St. Augustine (d. 430), the liberal arts were held to be a concomitant means for drawing men to truth and to God.[3]

However, under the new auspices of monastic, abbey, and cathedral schools, the basic thrust of the arts was shifted from their purely speculative to their religious and functional significance. This was probably due not only to the religious milieu but also to the exigencies of a less sophisticated and more largely rural society than that envisaged by those who had originally formulated the canon of the seven liberal arts—Plato in the *Republic* (book 7), Martianus Capella in the fifth century of our era, and Boethius in the fading light of Roman splendor in the early sixth century. The shift in emphasis was most notable in the mathematical arts of the quadrivium. Thus, arithmetic, which was earlier thought essential for anyone pursuing philosophy, was taught primarily in relation to calculation, principally for determining the date of the movable feast of Easter, also for use in weights and measures. Similarly, geometry was pursued not, according to the Boethian formula, as an example of continuous magnitude without motion, but as a useful instrument for land surveying or measurement, and for geography, surgery, and architecture. And astronomy, the study of the courses of the stars, was not studied primarily as a phenomenon of continuous magnitude in motion (as Boethius had put it), but, rather, for the practical purpose of calculating the times of movable church feasts and festivals according to the phases of the moon, as well as for specific religious offices. And finally, music was considered as an art to be performed, rather than as the philosophy of harmony or acoustics, with emphasis on the rules for both choral and instrumental performance.[4]

By the twelfth century, especially in the cathedral schools of such burgeoning urban centers as Chartres, Laon, Canterbury, Rheims, and Paris, the spectrum of studies had broadened. Masters and students were studying, in greater and ever widening perspective, mathematics, astronomy, and the more speculative sciences of nature on the basis not only of Plato's *Timaeus* and the writings of Boethius, Bede, Gerbert, and other traditional texts, but also, increasingly, of the works of Aristotle and the Arabs in the translations by John of Seville, Gundissalinus, Hermann the Lame, and others. Also, in these same cathedral schools we can see the beginnings of the characteristic

method of scholastic teaching, namely the disputation based on logic or dialectics, popularized by such a master as Abelard.[5]

Despite the hospitality of the cathedral and other ecclesiastical schools to the new developments in learning and scholarship, they were limited in the task of expanding the boundaries of that learning because their primary function was the preservation, propagation, and elucidation of the faith. It remained, therefore, for the corporate associations of scholars or universities to accomplish the task of developing, adapting, and broadening the aims and content of the body of knowledge. And, interestingly enough, they were greatly aided in this task by the newly established mendicant orders, the Dominicans and Franciscans, whose members, in order to enhance their evangelical and missionary efforts, encouraged scholarship in a variety of fields, including the natural sciences. The religious orders established houses of study in university centers and provided leisure and facilities for such prominent scholars as Roger Bacon, Albertus Magnus, Thomas Aquinas, John Pecham, and a host of others. Furthermore, the achievements of these and other members of the orders greatly enriched the intellectual life of the universities, despite occasional friction between the friars and secular university masters. Moreover, the friars supplemented papal efforts to establish and provide for studies in Arabic, Greek, Hebrew, and Chaldean (Aramaic or Syriac) at Paris, since Dominican and Franciscan evangelicalism fostered interest in and study of non-Western languages as well as a continuation of the contacts with the Muslim and Byzantine world that had been established earlier by the reconquest of much of the Spanish peninsula and the efforts of the crusaders in the Near East.[6] The intellectual expansion engendered by these continued contacts with non-Western peoples was early reflected in the curriculum of the schools, especially in the fields of natural philosophy and the mathematical sciences.

Before proceeding to these areas of the teaching program, we should draw attention to the fact that although the universities shared many features, they differed in several aspects which affected their teaching. For example, of the four archetypal universities—so called because they served as models for others—Paris, Oxford, Bologna, and Padua, the two northern universities were made up of masters or teachers primarily in the liberal arts, with student participation in university activities only through a master, while the earliest universities in Bologna and Padua were self-governing associations of students in law, with faculty prerogatives limited, at least in the statutes. The uni-

versities of arts and medicine at Bologna and Padua, also made up of students, were not organized until later in the thirteenth century. Moreover, in both Paris and Oxford, university members were largely clerics, supported, for the most part, by the returns from their ecclesiastical benefices, from which they had permission to absent themselves for purposes of study for a period of five to seven years. They were, thus, not dependent upon student fees or municipal salaries, as masters in Bologna and Padua were. In both the latter cities the masters or doctors (another term for teacher from the Latin *docere*, to teach) formed *collegia*, or colleges, of their own.

These doctors' *collegia* should not be confused with the colleges in all university centers founded by philanthropists to provide food and lodging and a small stipend for poor scholars or for those coming from a specified locality. As examples of those for poor scholars at Paris may be noted the College of Eighteen (Collège des Dix-huit); the College of the Good Children of S. Honoré, founded by Étienne Belot and his wife; and Ave Maria College, which took in small boys as well as those attending the university schools. Illustrative of foundations for scholars from particular localities were those of Beauvais, of Upsala, and of Skara—all at Paris. On the other hand, the Collège de la Sorbonne was founded by Robert de Sorbon to accommodate poor scholars pursuing advanced studies in the faculty of theology. In time, several of the colleges also became places of instruction as well as of lodging, as was true of the Collège de la Sorbonne. And at Oxford, Merton College, founded by Walter de Merton, became the principal center of mathematical and astronomical studies.[7]

Paris and Oxford

Since the differences between the northern and southern universities, noted above, were to have some effect upon the nature of the teaching, we shall draw attention first to the two northern university centers, and second to those south of the Alps. The consideration of the former first is not intended to imply that they were established earlier, a moot point at best, but, rather, to draw attention to the fact that the universities of Paris and Oxford appeared to have reached the zenith of their importance in mathematical, natural, and physical science, and medicine, in the thirteenth and fourteenth centuries and thereafter gave evidences of decline. On the other hand, many of the developments in science and medicine that had given great promise earlier in Paris and Oxford were carried forward in the later fourteenth, fifteenth, and sixteenth centuries in the university centers of Bologna

and Padua. One might suggest that the failure of the two northern universities to fulfill their earlier promise may be attributed to the cumulative and deleterious effects of the Hundred Years War, political upheaval, social unrest, the great Western schism, and the recurrent outbreaks of the Black Death.[8] For although the same or similar catastrophes afflicted the Italian cities, their effects were not augmented to the same extent by the devastation, exhaustion, and impoverishment resulting from the pursuit of the war on French soil, and the accompanying economic depression and political and social unrest that were rampant in England. Moreover, in the fourteenth and fifteenth centuries a number of new universities were established in the Germanies, in Bohemia, and elsewhere, for natives of those countries who formerly had gone to Paris, thus greatly reducing the internationalism of the University of Paris. Since the latter, nonetheless, provided the model for the newly founded universities, a brief overview of the principal features of that university, with reference also to Oxford, may be in order.

The University of Paris had emerged on the left bank of the Seine River at the close of the twelfth century as an autonomous association of masters or teachers primarily of liberal arts. Originally attached to the cathedral school of Notre Dame, these masters, as a result of the influx of students attracted from all parts of Europe by the fame of such teachers as Anselm of Laon, William of Champeaux, Peter Abelard, William of Conches, Gilbert de la Porrée, Peter Lombard, and others, had found it necessary to seek teaching quarters outside the cathedral walls in the open streets, under the shadow of the Abbey of Mont Ste. Geneviève, the Petit Pont, and in the vicinity of the Abbey of St. Germain des Prés. Thus removed from the immediate confines of the cathedral, the masters formed an association in the fashion of the contemporary guilds and sought and obtained recognition as a corporate body, independent of the jurisdiction of the cathedral chancellor, who was charged with the supervision of the cathedral school. Continuity with tradition was preserved, insofar as the cathedral chapter was concerned, through the retention by the chancellor of the right to confer the license to teach (*licentia docendi*) on candidates whose fitness had been determined by the masters. The university masters were encouraged and aided by the papacy, particularly popes Innocent III, Honorius III, and Gregory IX. The university also received royal recognition in the Great Charter of Privileges granted by King Philip Augustus in 1200, which extended royal protection and exemptions from local civic obligations and levies as well as from the jurisdiction of the local magistrates, to all members and associates or

clients of the university. The provost or mayor of the city of Paris was named as protector of these royal privileges. Moreover, one of the bishops other than the bishop of Paris, chosen in turn from among the bishoprics around Paris, served as conservator of the university's apostolic privileges. Hence, by the mid-thirteenth century the members of the university, under guarantees of royal and papal protection, were subject only to the jurisdiction of their own elected head, the rector. However, as clerics, they were still subject to the ecclesiastical guidance of the bishop of Paris and the chancellor of the Cathedral of Notre Dame.[9]

Many of the features described above were shared by the University of Oxford, although the latter differed from Paris in certain respects. For example, in the position of the chancellor, who, although relieved at Paris from the supervision of the teaching by university masters, nevertheless continued, by virtue of the fact that the masters were clerics, to exercise with the bishop of Paris some ecclesiastical guidance over them. At Oxford, by contrast, since both a cathedral and a cathedral school were lacking, the chancellor, appointed by the bishop of Lincoln, became the nominal head of the university, taking the place of the rector, the elected head at Paris. Also, of the two universities, Paris was more international in makeup, as evidenced by its division into the four nations: French, English-German, Picard, and Norman, representing the localities from which the masters came; while at Oxford, which remained largely insular in makeup, there was only the division of the masters into northern and southern parts of the British Isles. Paris, therefore, had the unique advantage, at least through the mid-fourteenth century, of sharing in the teaching services of distinguished scholars from all of continental Europe as well as from the British Isles.[10]

Both universities were organized for teaching purposes into the four faculties of arts, medicine, law, and theology. The arts faculty provided the basis and preparation for the three higher faculties of medicine, law, and theology; it also provided opportunities for preparatory studies in natural or physical science. A student without previous university work who arrived in Paris from England or one of the continental countries would first be assigned, by the proctor or head of the nation representing the locality from which he came, to a master of arts in that nation. After payment of a small fee (unless he had declared himself a pauper and was exempted from payment), the student's name would be entered on the matriculation roll maintained by the proctor. It is probable that the student would normally follow lectures in the preparatory arts of the trivium and quadrivium before

going on to the newer elements in the arts curriculum, including *physica* or natural science. At Paris the preparatory studies in grammar, or latin syntax, and literature, were gradually being reduced in scope in the later thirteenth and fourteenth centuries, and they were frequently relegated to the colleges or to special grammar schools maintained and supervised by the university.[11] Students preparing for the examinations for the baccalaureate and for the master of arts degree were in the early thirteenth century still required to have studied the time-honored Donatus and Priscian. But by the close of the thirteenth century, the classical grammarians were replaced at Paris by the newer *Graecismus* of Eberhard of Bethune and the *Doctrinale* of Alexander of Villa Dei. The Oxford curriculum continued to include Donatus and Priscian through the fifteenth century. On the other hand, at both Paris and Oxford, rhetoric, the art of persuasive discourse, although still required according to the early thirteenth-century statutes, appears to have disappeared from the statute requirements in the later thirteenth century, to reappear in the fifteenth century.[12]

Of the arts of the trivium, included in Paris under the new rubric of rational philosophy, only logic appears to have gained in scope and prestige. It was victor in both the allegorical and the actual battle of the seven arts. The chief explanation for this lay in the fact that logic provided the methodological basis for both philosophy and science, the two subjects that had fired the imagination and captured the enthusiastic attention of students and masters at Paris from the twelfth century onward. Hugh of St. Victor had suggested that logic should come first among the seven liberal arts, since, in his words, "it provides ways of distinguishing between modes of argument and the trains of reasoning themselves . . . it teaches the nature of words and concepts, without both of which no treatise of philosophy can be explained rationally."[13] And to this view was added the authority of such renowned thirteenth-century scholars and scientists as Robert Grosseteste, Bishop of Lincoln, prominent both at Oxford and Paris, and the two distinguished Dominican scholars, Albertus Magnus and Thomas Aquinas. All three held that since the study of logic provided the method for all sciences it should be placed first. Robert Grosseteste had apparently developed his own methodological approach to science from his prior study of Aristotle's *Posterior Analytics*, the work that was to provide the logical basis for the general physical theory of nature during the High and later Middle Ages. And Thomas Aquinas specifically asserted that the appropriate pedagogical sequence places logical topics first, since logic teaches the method for all philosophy and scientific inquiry.[14]

A differing view was that of Roger Bacon, who held to the priority of the study of mathematics. Bacon argued on the basis of the authority of Ptolemy and Boethius that mathematics was necessary to every discipline and science, since, according to Aristotle, the essential parts of philosphy, both natural and divine, are mathematical. Furthermore, he held that logic required mathematics, since its central core is based on the *Posterior Analytics*, which teaches the mathematical art of demonstration. Similarly, he continued, since logic begins with the *Book of Categories*, it is clear that the category of quantity cannot be known without mathematics. Indeed, there is no question in Bacon's mind but that mathematics is needed in every science. This, he affirmed, is further attested in the sixth book, twenty-second proposition of Euclid's *Elements*. And in Bacon's view, this necessity extends to all four parts of mathematics, namely, geometry, arithmetic, music, and astronomy. These, he held, were all founded when the human race began. Hence, according to Bacon, they should be studied first because through them one may advance to other sciences.[15]

The university documents are mute as to the outcome of this discussion on the order of study of the sciences. What does emerge is the preponderance of the texts required for logic, the subject that provided methodological rules for disputations and techniques for the pursuit of science. In 1215 works in the "old" logic, that is, the works in use in the West before about 1128, comprising Aristotle's *Categories* and *On Interpretation*, Porphyry's *Isagoge*, and the *Book of Six Principles* attributed to the logician Gilbert de la Porrée, were required, together with the "new logic," the works introduced in the later twelfth and early thirteenth centuries, namely, Aristotle's *Prior* and *Posterior Analytics, Topics*, and *Sophistical Refutations*—works which covered the subjects of syllogisms and the analysis of demonstration and proof. The number of works required in logic increased in succeeding years according to the statutes, with the addition principally of a number of systematic manuals and contemporary writings on logic, of which the most significant was the *Summulae logicales* of Petrus Hispanus, later Pope John XXI (d. 1277). This work, which dealt with the rules of syllogism and the doctrine of suppositions, was fruitful in developing a dialectical method of interpreting Aristotelian science, and perhaps also, as one author has noted, of explaining the results of direct observation.[16]

Although the statutes of Paris and Oxford leave little doubt as to the preponderance of logic, they are less explicit on the subject of the mathematical arts, except to note that at Paris these might be lectured on during feast days. Both Robert Grosseteste and Roger Bacon maintained that mathematics provides the gateway and key to all other sciences, and, as indicated earlier, Bacon urged that mathematics be studied before logic. However, despite the comparative lack of information in the documents regarding the mathematical or quadrivial arts, other evidence, such as the biographies of prominent scholars who lectured on these subjects at both Paris and Oxford, together with an extant list of required texts for the master of arts examination noted by an anonymous Parisian master, and other sources, testify to the teaching of these arts. For arithmetic, the required texts were the Latin translation or paraphrase of the Greek *Arithmetic* of Nicomachus of Gerasa by Boethius, on the theory of numbers, and the more elementary and practical abacus arithmetics and books on calculations, algebra, and Hindu numerals by the thirteenth-century author Jordanus de Nemore. In addition, the *Algorismus* of John of Sacrobosco, and the versified *Algorismus* of Alexander of Villa Dei, appear to have been utilized.[17]

For the study of geometry, the principal text was Euclid's *Elements*, according to the anonymous Parisian master. This work was also included in the Oxford curriculum with the specific admonition in the statutes that the candidate for inception as a teaching master affirm under oath that he had studied the first six books. The Euclidean *Elements* in the version of Boethius had long been utilized in the preuniversity schools. However, the work had been newly translated from the Greek in the course of the twelfth century, and was possibly also translated in the thirteenth century by Campanus of Novara, who wrote a commentary on it, as did Albertus Magnus and Roger Bacon. Thirteenth-century manuscripts of Campanus's commentary at Paris suggest its use there, especially since Campanus was a canon of the Cathedral of Notre Dame. In addition, at Paris and Oxford the twelfth-century *Practica geometriae* ascribed to Hugh of St. Victor may have been utilized, as well as the work of the same title by the thirteenth-century Italian Leonardo of Pisa. It is not clear whether two other works, namely, the tracts on optics of Alhazen and Witelo, either of which could be substituted for Euclid according to the stipulations of the Oxford curriculum before 1350, were also included at Paris. The importance of geometry, in addition to its practical uses carried over from the earlier teaching in the monastic and cathedral schools, was asserted by Roger Bacon and other ecclesiastics on the grounds that it was a useful instrument for the demonstration of theological truth. Moreover, both Robert Grosseteste and Roger Bacon insisted upon the necessity of geometry for a knowledge of natural philosophy, and agreed that of the mathematical sciences, geometry in particular could

explain the factual knowledge acquired through the physical sciences.

Of the other mathematical sciences, music continued to be taught in the thirteenth century from Boethius's *De musica*, which was still specified as the text in the fifteenth-century curriculum requirements for inception as master of arts at Oxford. Among the reasons set forth by Robert Grosseteste for including music in the curriculum was the importance of music in medicine and in promoting health. The question, too, of the effects of music on mind and body and the specific role of harmony in arousing the passions or elevating moral virtues provided a topic for discussion or disputation in the faculty of theology.

Finally, for astronomy, the fourth of the mathematical arts, the principal text, according to the anonymous Parisian master, was Ptolemy's *Almagest*, one of the most important sources of astronomical knowledge transmitted from antiquity. It had beome available for use by Western scholars in Latin translations from both the Greek and the Arabic in the course of the twelfth century. At Oxford, the curriculum also included a *Theorica planetarum*, or *Theory of the Planets*, which may refer to the work of that title by Campanus of Novara or to a work variously ascribed to the twelfth-century translators Gerard of Cremona and John of Seville, and to thirteenth-century authors such as John of Sacrobosco and Robert Grosseteste. The *Theorica planetarum* may also have been in use at Paris, where not only Ptolemy, but also the works of the Muslim astronomers Alfraganus, Albategni, and Alpetragius, and the Greek astronomer and geometer Theodosius of Bithynia, had become available in Latin translation in the course of the twelfth and thirteenth centuries. Hence, although Ptolemy was in the forefront, other works, in all likelihood, also provided the substance for disputations and lectures and the basis for compositions by contemporary authors. This was true, for example, of Sacrobosco's *Sphere*, which utilized Ptolemy and the Muslim authors Alfraganus and Albategni, and became the best known and most widely disseminated textbook in astronomy.

Mathematical studies, or the quadrivial arts, appear to have been followed by studies in physical or natural science, although the matter must remain somewhat conjectural. In any case, under the heading of natural philosophy, the arts curriculum in 1255 incorporated practically the entire Aristotelian corpus of natural philosophy, in the partly Arabo-Latin and partly Greco-Latin versions that had earlier been condemned at Paris largely because, upon first interpretation, they were deemed contrary to the faith by the Parisian ecclesiastical authorities.[18] The works on natural philosophy were also incorporated

into the curriculum at Oxford, where no prior condemnation had been issued. Among the works included in 1255 at Paris were Aristotle's *Physics, On the Heavens, Meteorology, On the Soul, On Generation, On Animals, On Sense and Sensibles, On Sleep and Waking, On Memory and Remembering, On Life and Death*, and the tracts of doubtful authenticity, *On Causes* and *On Plants*. Aristotle's *Metaphysics*, the subject of which constituted the third division in natural philosophy according to Thomas Aquinas, was also included among the prescribed texts in 1255. In addition, there was included with the Aristotelian writings the Arabic treatise in Latin translation *On the Difference between Soul and Spirit*, by Qusta ibn Luqa, a work relating to physiological psychology.[19]

Following natural philosophy in the arts curriculum at Paris was moral philosophy, which at both Paris and Oxford comprised Aristotle's *Ethics, Politics*, and *Economics*.[20]

In the foregoing account, attention has been drawn principally to the subjects and texts utilized in the arts faculty in the thirteenth and early fourteenth centuries at Paris and Oxford, the archetypal universities north of the Alps. Little change appears to have been made in offerings in the later fourteenth and early fifteenth centuries. The practice of Paris in this regard was followed by other universities, such as Toulouse, Montpellier, and the newly founded universities north of the Alps in the fourteenth and fifteenth centuries. Similarly, the methods and techniques of instruction that had been developed in the twelfth and thirteenth centuries remained much the same. These comprised the use of the lecture and commentary on a specific text, followed by the repetition or review of the matter covered and the *collatio*, or discussion, and conference. The master's function was chiefly to explain the text and to resolve difficult points. The lectures were usually divided into ordinary lectures, those given in the morning as part of the regular curriculum by members of the faculty, and extraordinary or cursory lectures, given usually in the late afternoon or on feast days by bachelors rather than by masters.[21] In addition, the lectures were supplemented by disputations, which applied rational methods of inquiry in the presentation, explanation, and proving of specific assertions or propositions, and the answering of objections raised against them. Frequent references were made in these disputations to the standard authorities—the Bible, the Fathers, Aristotle, and others. In addition, there were two other types of disputations held periodically during the school year. In the "Quodlibetal" disputation, at a public session, questions chosen at random from the leading topics of the day were put to the master in charge and were

first tentatively answered by a student closely associated with him. Then, at a later session, either twenty-four or forty-eight hours later, the master or professor made his formal presentation of the question in the form outlined above. In the other form of disputation, the "Disputed Questions," of which the *Questions on Truth* of Thomas Aquinas are an example, the master or professor set his own topic and then proceeded to give a formal disputation, again in the form noted above.[22]

The preceding survey of the subjects, textbooks, and techniques of teaching in the faculty of arts should make abundantly clear the generally profane or worldly nature of the curriculum of that faculty, despite the fact that at both Paris and Oxford, the masters were predominantly members of the clergy. The survey should also dispose of the claim often made that university scholars concentrated on theological studies to the exclusion of all else. At the same time, one should be mindful of the fact that the medieval concept of the ultimate aim of all learning was the discovery of truth, which in St. Augustine's formulation, influential throughout the Middle Ages, was synonymous with the love of God. Nevertheless, the masters of the individual faculties were zealous in their desire to maintain the institutional separation of the various fields of endeavor. They had a strong sense of the hierarchy of subject matter. At the pinnacle was the faculty of theology, the queen of the sciences; and to make this explicit, there were statutory prohibitions at Paris against the use of theological matter for lectures by the masters of the faculty of arts.[23] Theology and theological studies were reserved for the seasoned members of the theological faculties or for the schools of the monastic and mendicant orders. At Paris the faculty of theology was the smallest of the faculties, and in some of the other universities it was not included in the academic circle until the second half of the fourteenth century. The number of students who wished to undertake the long and arduous study required of candidates for the degree in theology was always small.

While there were prohibitions against members of the other faculties delving into and teaching matters pertaining to theological doctrine, there was no prohibition against theologians concerning themselves with profane subjects. Indeed, much of what they learned in their preparatory studies in the arts faculty was utilized by theologians in the exposition of theological texts. For example, theologians brought their knowledge of natural or physical science into lectures or commentaries on books of the Bible, especially on Genesis, dealing with the six days of creation, and into their commentaries on the *Sentences* of Peter Lombard (mid-twelfth century), based on the

Bible. Four distinctions or divisions (12–15) of book 2 of the *Sentences* relate to the work of corporeal creation. Hence, the lectures or commentaries on those sections by such distinguished theologians as Albertus Magnus, Thomas Aquinas, Bonaventura, and Duns Scotus (like the earlier Hexaemeral treatises) covered such matters of scientific interest as astronomical theories, physics (now incorporating Aristotelian material), optics, and biology.[24] Albertus Magnus, in particular, was convinced of the importance of profane science. In commenting on the *Sentences*, he had asserted that in matters of faith he would follow Augustine, but in matters of science, he preferred a scientific master: for medicine, Hippocrates or Galen; and for natural philosophy, Aristotle. Albertus Magnus also departed somewhat from the view that all investigation of the natural world should be for the service of God, in asserting that he was undertaking his investigations to satisfy his students' curiosity and, we may assume, his own.[25]

Besides the concern with natural science or philosophy by members of the arts faculties of Paris and Oxford, and by members of the faculty of theology, there was also a manifest interest in this subject by members of the faculty of medicine. Although at Paris and Oxford the institutional separation of arts and medicine into two separate faculties was maintained, there was, nevertheless, a close association between them. Students matriculating in medicine were required to have had preliminary training in arts, and this same requirement was applied to candidates for the license to teach medicine as well as to those wishing to practice it. Certain physicians of the late twelfth and thirteenth centuries appear to have taught, probably sequentially, in both the arts and medical faculties at Oxford and perhaps also at Paris. For example, Alexander Neckham, Alfred of Sareschal, and Raoul de Longchamps reportedly did so. Although they were already physicians, these men were also among the earliest university scholars to utilize the newly translated Aristotelian works in natural philosophy.[26]

This is not the place to assess the actual achievements of those who lectured, disputed, and observed natural phenomena in the course of their sojourn in the university centers of Oxford and Paris. But there can be little doubt, if the regulations were obeyed, of the breadth and depth of the curriculum in logic, mathematics, and natural philosophy.

Bologna and Padua

In medieval Italy, too, from the thirteenth century onward, the university, as an institutionalized association of scholars, was the chief

focus of learning in the sciences. Of the numerous and sometimes short-lived universities of medieval Italy, those of Bologna and Padua were among the oldest and most prestigious; they provided not only an institutional model but also a continuing source of intellectual stimulation for similar associations in other cities.

At Bologna and Padua the first formal associations of scholars were of foreign (that is, non-Bolognese and non-Paduan, respectively) students of civil and canon law. Subsequently, at Bologna, probably at some time during the last forty years of the thirteenth century, they were followed by another university made up of those studying liberal arts and medicine. It was chiefly by the members of these universities of arts and medicine and their instructors that study and teaching of the sciences was pursued, as the following discussion will make plain.

The student universities of law and of arts and medicine were, like the universities of masters in northern Europe, self-governing corporations electing their own officials—the rectors, proctors, and consilarii—and making their own rules and regulations pertaining to teaching practices and curriculum. The members of the student universities also claimed the right to elect professors to a small number of salaried chairs. In the universities of arts and medicine of Bologna and Padua, only students who had studied medicine might vote for professors of medicine, only students who had studied logic for professors of logic, and so on.[27] Nevertheless, student control of faculty and curriculum, however specifically and impressively asserted in the statutes drawn up by the students themselves, was, in practice, greatly weakened by municipal payment of professors' salaries and by the fact that the conduct of examinations remained in the hands of the faculty.[28] Probably at about the same time as a student university of arts and medicine appeared at Bologna, some of the teaching masters of arts and medicine, who were citizens of Bologna and, hence, not normally members of the foreign students' university, organized themselves into a doctoral college. A similar pattern was followed at Padua, where some form of association of students of arts and medicine had been established by 1262, although the University of Arts and Medicine did not achieve full legal sanction until 1399. At Padua, too, a doctoral college of arts and medicine was formed; it was already in existence by 1307, when its members included professors of medicine (at least one of whom also taught philosophy and astrology), logic, and grammar. Padua, however, differed from Bologna in that its citizens were officially debarred from the professorial chairs by a frequently violated municipal statute.[29] It must be reemphasized that the doctoral

colleges were quite separate and distinct from colleges of another type, namely, those founded by specific benefactors to provide stipends and lodgings for students. Colleges of the latter type came into existence in Bologna and Padua as well as at Oxford and Paris.

The professional and intellectual opportunities provided for teaching and study of arts and medicine in both Bologna and Padua attracted men of learning from far and near. Not all of those who came were formally members either of a doctoral college of arts and medicine or of the corresponding student university. The university locale in which those institutions functioned also embraced such a man as the surgical writer Theodoric of Lucca (d. 1295), a bishop residing outside his see, who flourished and probably taught in the city of Bologna for many years without apparently having official affiliation with any academic association.[30]

The curricula of the universities of arts and medicine included the study of mathematical and physical as well as medical science. By the close of the thirteenth century, in Italy as elsewhere, the normal arts curriculum comprised not only the verbal and mathematical disciplines of the trivium and quadrivium, but also the study of philosophy and natural science in the Aristotelian works on metaphysics, physics, the soul, the heavens, animals, and so forth. Moreover, the scientific portion of this curriculum was studied not only by those pursuing a degree in arts as their final goal but also by all those intending to proceed to the study of medicine. Logic, the fundamental tool of scholastic methodology in all branches of learning, astrology (essential to medicine in an age in which the reality of planetary influences upon human physiology and psychology was almost universally accepted), and natural philosophy were regarded as particularly important preparatory studies for physicians. As Peter of Abano (d. ca. 1316), professor of philosophy, astrology, and medicine at Padua, remarked, while all the arts and sciences are necessary to medicine, logic, astrology, and natural science (*scientia naturalis*) are "most necessary."[31] Accordingly, the 1405 statutes of the Bolognese student university of arts and medicine listed texts for medicine (theoretical and practical), for philosophy, and for astrology in a single section. (Set books for logic, studied from the works of Aristotle, and surgery are prescribed in other, separate, sections.) For the compilers of these statutes, "philosophy" meant the study of Aristotle's works on natural science and selections from his *Metaphysics*. "Astrology," a basic course in arithmetic, geometry, and astronomy (including the use of astronomical instruments), was presumably designed to equip the student with the necessary knowledge to make his own astrological determinations

for medical or other purposes. The works assigned him for the study or mastery of this subject include an algorism, or arithmetic, the first three books of Euclid's *Elements*, the *Sphere* (presumably of Sacrobosco), the *Theory of the Planets* (perhaps that of Campanus of Novara), the *Centiloquium* ascribed to Ptolemy and part of his *Almagest*, Messahala's treatise on the astrolabe, and the Alfonsine Tables. Among the textbooks for theoretical medicine were the *Aphorisms* and *Prognostics* of Hippocrates, the *Tegni* and other works of Galen, and extensive selections from the *Canon* of Avicenna. The latter work was also the sole text prescribed for the study of practical medicine. Surgery, too, required the student to be familiar with portions of the *Canon* as well as with the seventh book of the *Liber ad Almansorem* of Rasis and the more recent work of the thirteenth-century writer Bruno Longoburgo of Calabria.[32]

The close union of natural philosophy or science with arts and medicine is further exemplified in the descriptive terminology applied to the many individuals with degrees in "arts and medicine" or "medicine and philosophy." Moreover, it was quite usual for a master to give lectures on the Aristotelian works on natural science or on the liberal arts (usually logic or astronomy) as well as on medicine during the course of his career. For instance, of fourteen doctors involved in formulating the 1378 statutes of the medical branch of the Bolognese College of Doctors of Arts and Medicine, seven are recorded as having degrees in philosophy as well as medicine, and five are known to have taught logic and Aristotelian natural philosophy along with medicine.[33]

A number of works by masters associated with the Italian faculties of arts and medicine who are primarily identified as physicians testify both to the dialectical and philosophical training of their authors and to the breadth of their interest in natural science. To give only three examples, an abbreviated Italian translation of the *Nicomachean Ethics* was prepared by Taddeo Alderotti (d. 1295), professor of medicine at Bologna; an extensive and learned commentary on the natural problems attributed to Aristotle was written by Peter of Abano; and Jacopo de'Dondi, professor of medicine at Padua, produced treatises on tides and hot springs. It seems that an individual master might teach more or less any combination of logic, mathematical and physical science, speculative natural philosophy, and medicine. In some instances the teaching of arts and natural philosophy occurred at an early stage of a master's career before he was qualified to teach medicine, as was the case with William of Brescia, who taught logic and philosophy at Padua in the 1270s and 1280s before proceeding to study medicine

at Bologna,[34] but this sequence does not appear to have been invariable. Of course, not every professor of physical or mathematical science or natural philosophy in the Italian schools also taught or wrote on medicine, as the surviving output of some of these men makes clear. Thus, in the fourteenth century a number of discussions of questions of natural philosophy were produced by Bolognese scholars who apparently left no medical works, while, for example, among professors at Padua, Blasius of Parma (d. 1416) seems to have written only on mathematics and natural philosophy—and Prosdocimo de'Beldomandi (d. 1428) only on mathematics, astronomy, and music.[35] Nonetheless, the only inviolable division within the faculties of arts and medicine in terms of personnel was apparently between the teachers of grammar and rhetoric on the one hand and those of logic, mathematical and physical science, and medicine on the other. Moreover, since both natural philosophy and theoretical medicine were approached as branches of speculative science, the organization of teaching in these two fields had many features in common. Scholars in both disciplines lectured and produced commentaries upon authoritative works and disputed questions of particular interest. The distinctive feature of medical instruction was the division into theory and practice, which, as noted above, was embodied in the curriculum at Bologna by 1405.

Despite the institutional, intellectual, and personal union of mathematical and physical science with medicine in the universities of arts and medicine, the separate identity of each branch of study was carefully preserved by statute and, apparently, in practice. The Bolognese and Paduan universities of arts and medicine reflected in their statutes a desire on the part of the compilers to prevent the dilution of the curriculum through the blurring of the lines between disciplines and the admission of unqualified students to the more advanced studies. The subjects of the curriculum were arranged in a hierarchy in which medicine held the highest place. Only scholars who had studied (and at Bologna only masters who had taught) a particular subject might take part in public disputations pertaining to that discipline.[36] And although astrology and natural science were regarded as peculiarly appropriate preparation for the would-be medical student, the content of study in those areas was certainly not narrowed to serve purely medical ends. On the contrary, significant independent development took place. At Bologna an important group of radical Aristotelian or Averroist masters of arts and teachers of philosophy and natural science emerged during the early decades of the fourteenth century. The members of this group appear to have been closely in touch with con-

temporary developments in philosophy and natural science in the university centers north of the Alps.[37] At Padua, Jacopo and Giovanni de'Dondi, professors of medicine, who, like Peter of Abano before them, also taught astrology, made contributions to astronomy and related sciences that went far beyond medical astrology. Both Jacopo, the father, and Giovanni, the son, were renowned for their achievements as clockmakers; the younger Dondi designed and constructed an elaborate mechanical device to illustrate the movements of the planets.[38] In addition, mathematics at Padua had emerged as a separate discipline, independent of music and astrology, by 1389. In that year a professorial chair was apparently established in the subject. However, according to the university statutes of 1495, extraordinary—that is, junior—lecturers could still be appointed at random to teach any one of the subjects of philosophy, astrology, mathematics, or medicine.[39]

Arts, natural philosophy, and medicine could be studied either simultaneously or consecutively. A degree in arts seems to have called for four years study and a degree in medicine for four or five. At Bologna, students were permitted to specialize by concentrating on particular disciplines within the general category of arts and natural philosophy. For example, a student could choose to be examined either in all the arts and philosophy, in logic and philosophy alone, in grammar and rhetoric, in philosophy and astrology, or in medicine and one or more of the arts. For a general arts degree, a two-day examination was required, a similar examination for a degree in logic and philosophy. Grammar with rhetoric, or philosophy with astrology, also required only a single examination of one day's duration. If any three subjects were combined, two examinations were required, while a degree in medicine and all the other arts was granted only after three examinations. As for medicine itself, "if anyone wants to pass with distinction, then he is to take two examinations"—perhaps one in theory and the other in practice.[40]

The main features of the curriculum just described endured with relatively minor additions and modifications for several centuries. From the thirteenth century onward, the university centers acted as magnets to draw together all those concerned with Aristotelian natural philosophy, astronomy or astrology, and medicine. The grouping of disciplines in the faculties of arts and medicine thus had a lasting influence on Italian scientific life, and one to which a variety of developments, both intellectual and social, can be traced. For instance, scientists educated in the Italian university centers very commonly had medical training, even though their principal achievements were sometimes in quite unrelated fields: Copernicus is an excellent example. Moreover, the association of liberal arts and natural philosophy with medicine in university teaching and organization must surely have reinforced the belief of many academic physicians that medicine itself was an intellectual science, related to natural philosophy in its principles and methodology. Taddeo Alderotti, for example, explained that theoretical medicine derives its principles from, and, hence, is a subdivision of, natural science (*scientia naturalis*). Natural science, he maintained, deals with bodies in general, including the human body, while medicine deals with the human body alone.[41] Taddeo's statement is indicative of the importance attached to physical or natural science as well as logic as a foundation for medical study. It may be added that in the view of some historians the dialectical training of learned physicians in the universities of arts and medicine contributed significantly to the development of scientific methodology.[42]

At Bologna and Padua the study of mathematics and physical science was more likely to be undertaken with a vocational purpose than was true for Oxford or Paris. In the two Italian universities, as in the university centers north of the Alps, these disciplines were classified as branches of speculative philosophy, whose function it was to yield knowledge for its own sake. But this aim was modified in the medically oriented faculties of arts and medicine in Italy. Scholars there had, in addition, a very practical incentive to study astrology (including astronomy) and Aristotelian natural philosophy, since these subjects served as preparation for the prestigious and lucrative medical profession. No doubt, many future physicians treated the study of nonmedical sciences as a preliminary stage of their education, to be passed through as quickly as possible. But some, such as Taddeo Alderotti and Peter of Abano, seriously concerned themselves with "reconciling the differences of the philosophers and physicians."[43] This endeavor can perhaps be seen as an attempt to create a unified science of man, which would draw impartially upon the scientific works of Aristotle and of Galen and other medical authorities.

The link between arts, natural philosophy, and medicine also meant that in some cases the economic and social arrangements supporting the teaching of mathematical and physical science differed in the Italian university centers from those in their northern counterparts. In the north, as has been noted above, almost all the thirteenth- and fourteenth-century scientists associated with the university centers were clerics, many of them members of religious orders; their scientific activities and teaching were thus supported by ecclesiastical resources. This was not necessarily the case in Italy. There, from the time the

academic universities and colleges of arts and medicine were established, their senior members were in many cases married laymen. That this became the norm is demonstrated by the statutes of the Bolognese College of Doctors of Arts and Medicine (1378), which give preference to the sons of members,[44] and by the rise of veritable professional and learned dynasties such as, in medicine, the del Garbo and Santa Sofia families, and, in astrology and astronomy, the Dondi family. Municipal governments in the Italian university centers normally funded a few salaried chairs in logic, philosophy, astrology, and, at Padua in the later fourteenth and fifteenth centuries, mathematics. In addition, the Bolognese student university statutes of 1405 make provision for the collection by faculty members of fees from students on an individual basis.[45] It is plain, however, that medical practice was the chief means of support of many teachers of medicine[46] and, therefore, conceivably of some teachers of mathematical and physical science, since certain of these men, as noted above, also taught medicine. In Italy as in the north, those learned in astrology could, of course, also contribute to their support by preparing prognostications for private clients or by entering the service of a prince. The latter course, for example, is said to have been chosen by the famous astrologer Guido Bonatti (d. after 1282), who was probably a professor at Bologna.[47] In 1405 professors of astrology at Bologna were obliged by university statute to provide individual prognostications or "judgments of the year" without charge for scholars of the University of Arts and Medicine, a requirement that may indicate that it was normal for professors to prepare such judgments for other clients for a fee.[48]

On the whole, the institutionalization of the sciences in association with medical education in the Italian faculties of arts and medicine probably benefited the development of science. Because the institutional and intellectual links between logic, astrology, natural science, and medicine drew to the study of the sciences many who were attracted by a medical career, authors and teachers who wished to specialize in astrology (and astronomy), mathematics, and natural philosophy were assured of a constant flow of students, and, hence, of a secure institutional position. This, in turn, made it possible to extend the scientific part of the curriculum. For example, the provision of a separate chair of mathematics at Padua—a chair held at different times by such noted mathematical authors as Blasius of Parma, Prosdocimo de'Beldomandi, and Regiomontanus (d. 1476)—developed as an offshoot of the chair of astrology. And the demand for the teaching of astrology, as already demonstrated, was directly linked to the needs of medical education as then conceived.

Notable scientists flourished in the environment of the medieval universities—such men as Buridan, Oresme, and the members of the fourteenth-century Merton school come to mind. Yet in the long run, the contribution of the medieval university to the development of science was perhaps less in the achievements of its great men than in the fact that it was the first educational institution in the history of Europe to impose some elements of systematic and organized training in scientific subjects upon large numbers of people. Upon this foundation, the legacy of the Middle Ages, later generations could build.

Notes

1. Pearl Kibre has prepared the introductory portions of this essay as well as the section relating to the universities north of the Alps; Nancy Siraisi has written the sections on the universities south of the Alps. However, both authors have attempted to integrate their efforts throughout.

2. Hastings Rashdall, *The Universities of Europe in the Middle Ages*, ed. Frederick M. Powicke and A. B. Emden, 3 vols. (London, 1936), 1:4–8, 151–52, 220–31, 283–87; Pearl Kibre, "Scholarly Privileges: Their Roman Origins and Medieval Expression," *American Historical Review* 59 (1954):543–67; also her *Scholarly Privileges in the Middle Ages* (Cambridge, Mass., 1962), chap. 1; and Etienne Delaruelle, "De la croisade à l'université. La fondation de l'université de Toulouse," in *Les universités du Languedoc au XIII^e siècle* (Toulouse, 1970), pp. 23–24.

3. James A. Weisheipl, O.P., "Classification of the Sciences in Medieval Thought," *Mediaeval Studies* 27 (1965):54–62; James Westfall Thompson, *The Literacy of the Laity in the Middle Ages* (Berkeley, 1939), especially chap. 1; Lynn Thorndike, *A History of Magic and Experimental Science*, vol. 1 (New York, 1923), chap. 21 and especially pp. 485–87, on "Christianity and Natural Science"; also Pearl Kibre, "The Christian: Augustine," in *The Educated Man: Studies in the History of Educational Thought*, ed. Paul Nash, Andreas M. Kazamias, and Henry J. Perkinson (New York, 1965), p. 98.

4. M. L. W. Laistner, *Thought and Letters in Western Europe, A.D. 500 to 900* (Ithaca, 1957), chap. 4; Pierre Riché, *Education et culture dans l'occident barbare, VI–VIII^e siècles* (Paris, 1962), pp. 108–11, 146–56, 237–38, 247–49; William H. Stahl, *Martianus Capella and the Seven Liberal Arts* (New York, 1971), pp. 154–70; Pearl Kibre, "The Boethian *De Institutione arithmetica* and the Quadrivium in the Thirteenth-Century University Milieu at Paris," in *Boethius and the Liberal Arts*, ed. Michael Masi (Nashville, forthcoming); and Lowrie J. Daly, S.J., *The Medieval University* (New York, 1961), pp. 8–10.

5. A. Forest, Fernand van Steenberghen, and Maurice de Gandillac, "Le mouvement doctrinal du XI^e au XIV^e siècle," in *Histoire de l'église*, vol. 13 (Paris, 1951), 1ff.; M. L'Abbé A. Clerval, *Les écoles de Chartres au moyen âge (du V^e au XVI^e siècle)* (Paris, 1895; reprinted Frankfurt a.M., 1965), pp. 108–30, 235–48. For a recent study of the twelfth-cen-

tury approach to natural science see Brian Stock, *Myth and Science in the Twelfth Century* (Princeton, 1972); also M.-D. Chenu, O.P., *Nature, Man and Society in the Twelfth Century*, trans. Jerome Taylor and Lester K. Little (Chicago, 1968).

6. Van Steenberghen, *Histoire de l'église*, 13:182ff.; Pearl Kibre, *The Nations in the Mediaeval Universities* (Cambridge, Mass., 1948), pp.; 98–99; also *Chartularium universitatis Parisiensis*, ed. Heinrich Denifle and Emile Chatelain, 4 vols. (Paris, 1889–97), 1:nos. 180–182, for the efforts of Pope Innocent IV, in 1248, to establish and promote the study of Arabic and other non-Western languages.

7. Astrik L. Gabriel, *Skara House at the Mediaeval University of Paris* (Notre Dame, Ind., 1960); Gordon Leff, *Paris and Oxford Universities in the Thirteenth and Fourteenth Centuries* (New York, 1968), pp. 113–15.

8. For the situation particularly in Paris in the fifteenth century, see Pearl Kibre, *Scholarly Privileges*, chap. 6; and for Oxford, ibid., especially pp. 317–19; and Anna M. Campbell, *The Black Death and Men of Learning* (New York, 1931), chap. 6.

9. Astrik L. Gabriel, *Garlandia: Studies in the History of the Mediaeval University* (Notre Dame, Ind., 1969), chaps. 1 and 2.

10. Rashdall, *Universities*, 1:275–82; 3:37, 41–47; Pearl Kibre, *Nations in the Mediaeval Universities*, pp. 160–63.

11. Gabriel, *Garlandia*, chap. 4; "Preparatory Teaching in the Parisian Colleges during the Fourteenth Century."

12. Louis J. Paetow, *The Arts Course at Medieval Universities with Special Reference to Grammar and Rhetoric* (Urbana, Ill., 1910), chaps. 1 and 2; also Philippe Delhaye, "La place des arts libéraux dans les programmes scolaires du XIII^e siècle," in *Arts libéraux et philosophie au moyen âge. Actes du Quatrième Congrès International de Philosophie Médiévale* (Montreal, 1969, henceforth cited as *Arts libéraux*), pp. 168–70; *Statuta antiqua universitatis Oxoniensis*, ed. Strickland Gibson (Oxford, 1931), pp. 25–26; and James A. Weisheipl, O.P., "Curriculum of the Faculty of Arts at Oxford in the Early Fourteenth Century," *Mediaeval Studies*, 26 (1964):168–70.

13. Hugh of St. Victor, *Didascalicon: A Medieval Guide to the Arts*, trans. Jerome Taylor (New York, 1961), p. 59.

14. Pearl Kibre, "The Quadrivium in the Thirteenth-Century Universities (with special reference to Paris)," in *Arts libéraux*, pp. 178–79.

15. Ibid., p. 178.

16. Frederick M. Powicke, *Ways of Medieval Life and Thought* (London, 1949), pp. 189–94; Heinrich Roos, "Le trivium à l'université au XIII^e siècle," in *Arts libéraux*, p. 196.

17. Pearl Kibre, "The Quadrivium in the Thirteenth-Century Universities," in *Arts libéraux*, pp. 176–83; and for Oxford, Weisheipl, "Curriculum of the Faculty of Arts at Oxford," pp. 170–73, cover this and the remaining quadrivial arts.

18. For the prohibitions see James A. Weisheipl, *The Development of Physical Theory in the Middle Ages* (Ann Arbor, 1971), pp. 26–27; also Daly, *Medieval University*, pp. 81–83.

19. Chartularium universitatis Parisiensis, vol. 1, no. 246; Weisheipl, "Curriculum of the Faculty of Arts at Oxford," pp. 173–76; Thorndike, *History of Magic*, 1:657–61.

20. Weisheipl, "Curriculum of the Faculty of Arts at Oxford," p. 175.

21. On lecturing, see Daly, *Medieval University*, pp. 151–56.

22. On the technique of the disputation, see ibid., pp. 156–58; also P. Glorieux, *La littérature quodlibétique*, 2 vols. (Kain-Paris, 1925–1935).

23. *Chartularium universitatis Parisiensis*, vol. 1, no. 441, statute of the faculty of arts, for April 1, 1272.

24. Thomas Aquinas, *Summa theologiae*, ed. and trans. William A. Wallace, O.P. (Dover, Mass., 1967), 10:xx–xxi; appendices 3–9, and especially pp. 213–16.

25. Albertus Magnus, *Commentarii in secundum librum Sententiarum*, dist. 13C, art. 2, in *Opera omnia*, ed. Auguste Borgnet, vol. 27 (Paris, 1894), p. 247; *De vegetabilibus et plantis*, bk. 6, tract. 1, in *Opera omnia, ed. Borgnet*, vol. 10 (Paris, 1891), pp. 159–60.

26. For license requirements see *Chartularium universitatis Parisiensis*, vol. 1, nos. 444, 451–56; vol. 2, nos. 921, 922, 996; vol. 4, no. 2659. See also Alexander Birkenmajer, "Le rôle joué par les médecins et les naturalistes dans la reception d'Aristote au XII^e et XIII^e siècles," *Studia Copernicana*, vol. 1 (Warsaw, 1970), pp. 73–97, especially p. 77ff.

27. Carlo Malagola, ed., *Statuti delle università e dei collegii dello Studio Bolognese* (Bologna, 1888), pp. 261–64; *Statuta dominorum artistarum academiae patavinae* (Padua, n.d.; Hain 15015), statutes of 1465, fol. 25r–v.

28. Kibre, *Scholarly Privileges*, pp. 42–51, 61–63.

29. Nancy G. Siraisi, *Arts and Sciences at Padua* (Toronto, 1973), chap. 1.

30. Mario Tabanelli, *La chirurgia italiana nel'alto medioevo* (Florence, 1965), 1:198–210.

31. *Conciliator differentiarum philosophorum et praecipue medicorum* (Venice, 1496), diff. 1, fol. 3r.

32. Malagola, *Statuti*, pp. 274–77, 251–52, 247–48.

33. Ibid., pp. 425–26, 448.

34. George Fowler, *Intellectual Interests of Engelbert of Admont* (New York, 1947), pp. 21–22.

35. Regarding philosophy at Bologna, see Charles Ermatinger, "Averroism in Early Fourteenth Century Bologna," *Mediaeval Studies* 15 (1954):35–56; the same author's "Some Unstudied Sources for the History of Philosophy in the Fourteenth Century," *Manuscripta* 14 (1970): 67–87; and bibliography there cited.

36. Malagola, *Statuti*, pp. 261–64 (1405); *Statuta dominorum artistarum*, fol. 21v (1465).

37. See note 35, above.

38. Thorndike, *History of Magic*, vol. 2 (New York, 1923), pp. 874–947; vol. 3 (New York, 1934), pp. 386–97; and Silvio A. Bedini and F. R. Maddison, *Mechanical Universe: The Astrarium of Giovanni de'Dondi* (Philadelphia, 1966); Lynn White, Jr., "Medical Astrologers and Late Medieval Technology," *Viator* 6 (1975):295–308.

39. Antonio Favaro, "I lettori di matematiche nella Università di Padova," *Memorie e documenti per la storia della Università di Padova*, vol. 1 (Padua, 1922), p. 25; *Statuta dominorum artistarum*, fol. 21v.

40. Malagola, *Statuti*, p. 432 (doctoral college statutes, 1378), pp. 274–75 (student university statutes, 1405), p. 489 (fragment of doctoral college statutes, undated).

41. *Expositiones . . . in subtilissimum Joannitii Isagogarum libellum* (Venice, 1527), fol. 343r–v.

42. John H. Randall, *The School of Padua and the Emergence of Modern Science* (Padua, 1961).

43. In his commentary on the *Isagoge* of Johannitius, Taddeo habitually broke down his material into (1) the opinion of the philosophers and (2) the opinion of the physicians, and then attempted reconciliation (see, for example, fol. 344v of the cited edition). The title of Peter's principal work, the *Conciliator*, indicates the same purpose.

44. Malagola, *Statuti*, p. 438. One may contrast with this the contemporary situation in England, where a substantial majority of educated physicians were still clerics. See Huling E. Ussery, *Chaucer's Physician: Medicine and Literature in Fourteenth-Century England* (New Orleans, 1971), pp. 29–30, 35–38, 40.

45. Malagola, *Statuti*, pp. 248–49.

46. Of the many examples that could be cited, two will suffice: Bartolomeo da Varignana, who taught medicine for many years at Bologna, attended the Emperor Henry VII on his ill-fated expedition to Italy; Gentile da Foligno (d. 1348), author of copious commentaries on Avicenna and a professor in various university centers, was the personal physician of Ubertino da Carrara, ruler of Padua.

47. Thorndike, *History of Magic*, 2:827–28.

48. Malagola, *Statuti*, p. 264.

5 Mathematics

Michael S. Mahoney

The development of mathematics in medieval Europe from the sixth to the fifteenth century shows clearly how mathematics depends on the cultural context within which it is pursued.[1] The barbarian cultures that succeeded Roman rule in the fifth century had no indigenous mathematical traditions; in mathematics, as in most other intellectual activities, they followed the Roman lead. But the Romans themselves had had little interest in mathematics beyond its practical application to business and surveying. Roman thinkers who wished to learn the theoretical mathematics of Euclid, Archimedes, or Apollonius did so in the same way they learned the philosophy of Plato or Aristotle—in its original Greek from Greek teachers. But Greek theoretical mathematics received no reinforcement from native Roman intellectual traditions, with the result that those few Romans who learned the subject made no contributions to it. Greek habits of mathematical thought made little or no impact on Roman culture, and Greek mathematics remained in Greek down to the end of the Empire.[2]

In mathematics, then, to succeed the Romans was to succeed to nothing beyond the rudiments of computational arithmetic on the abacus and of mensurational geometry immediately applicable to surveying and architecture. The fragments of Greek mathematics that Boethius (d. 524/25) tried to preserve by translating Nicomachus of Gerasa's *Arithmetic* and a portion of Euclid's *Elements* constitute a measure not of how little mathematics survived the fall of the Empire, but of how little had been present there before. Not only did the new cultures lack