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# THE ADOPTION OF AL-FARABI'S "MATHEMATICAL SCIENCES" IN THE MEDIEVAL WEST: A Study in Cross-Cultural Borrowing

It is a truism recognised in all modern textbooks in both Western and World Civilisation that the medieval Islamic civilisation transferred the accomplishments of Greek science to the Latin West. As is well known, this was largely accomplished in Christian Spain after the *Reconquista* (i. e., after 1085) and slightly later in Sicily. Cross-cultural borrowing of this type was, as William McNeill said, "one of the principle stimuli to innovation" in the receiving civilisation.[1] Prior to the twelfth-century translations of Greek and Arabic texts, the Carolingian heritage in "scientific study" was of a derivative and secondary character, more likely to cite Virgil or Macrobius as authorities than any scientific writer of Anti-quity.[2] This was particularly evident in the sciences of the *quadrivium*, given that "All *quadrivium* studies languished in the Latin world [of late antiquity] and geometry was the most neglected subject of the four."[3] As the centuries passed, the situation grew even worse, primarily as the result of there being very few ancient works available to medieval scholars on any of the sciences of the *quadrivium*. However, if we look at the guidelines for the "Divisions of the Sciences" and the lists of readings required for degrees in the thirteenth and fourteenth centuries, we see a renewed emphasis on the mathematical sciences. It is my contention that not only was the Arabic influence decisive for this innovation, but the particular path of influence in these sciences was the result of the translation and appropriation of curricular guides that had been written by Islamic scholars for their own students who wished to study ancient philosophy and natural sciences, which they called the "Ancient" or "Foreign" sciences. By studying the translation of one of these guides we can see not only what the "new" curriculum of the Islamic scholars contained, but we can also gain insight into the limits of the scientific knowledge

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1William McNeill, *A World History* (New York, 1971), 127.

2Margaret Gibson, "Continuity of Learning Circa 850-Circa 1050," *Viator* 6 (1975):9-12.

3William H. Stahl, *Martianus Capella and the Seven Liberal Arts* (New York,1971), 127.

of the Christians who translated these texts. In other words, the translating process can be a window on both the cross-cultural borrowings and a reflection of the state of Christian learning in these sciences.

Among the many of these guides that existed, the one that was considered "indispensable" in Muslim Spain was al-Farabi's *Book of the Enumeration of the Sciences, Kitāb Iḥṣa' al-ʿulūm).*[4] *The Enumeration* is primarily an education text. In it al-Farabi says that he is describing the parts of all the "well-known sciences" of his day so that anyone can pick up the book and put it to good use. In the twelfth century it was felt to be the key to the science of the Arabs and thus provided a guide to the ancient philosophical works for which both scholars in the Muslim world and the Latin West felt an acute need. In part, the value of the book comes from its contents: it is, as Sāʿid al-Andalusi remarked, a rather straightforward description of what makes up each individual field of knowledge.[5] However, one should not think of it as a textbook. Rather it is more like a syllabus or curriculum, describing in the broadest contours what a scholar would need to know: Al-Farabi tells the reader what all the subjects are that make up the "well-known sciences", then he presents the topics that one would need to study within each subject in order to know that subject. Near the end of each topical section, reference is usually made to the known books of Aristotle (some of which we now know to be written by someone other than the Stagirite) or of some other ancient authority, such as Euclid. The result is a curriculum which, if followed, would introduce the student to all the parts of classical philosophy, including mathematics, natural science, and metaphysics. For our purposes, of all the translated curricular guides it is also the most fruitful to study because it was translated into Latin by Dominicus Gundisalvus and the great Gerard of Cremona, two

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[4]Thus it was called by Ṣāʿd al-Andalusi, *Science in the Medieval World: Book of the Categories of Nations*, tr. Sema'an I. Salem and Alok Kumarā, (Austin, 1991), 50. There is no English translation of the whole text of the *Ṭabaqāt al'Umam* available. The most accessible edition is that of Angel González Palencia, *Catálogo de las Ciencias* (Madrid, 1953), which contains the Arabic text based upon the Escorial manuscript, a Spanish translation, Gerard of Cremona's Latin translation, and Dominicus Gundisalvus's version according to its first published edition. The two Latin translations are not critical editions. For a "critical" reconstructed edition of Gundisalvus, see M. M. Alonso, *De Scientiis* (Madrid, 1954), which also includes as an appendix the passages reproduced by Vincent of Beauvais in his *Speculum Doctrinale*. The only English translation of any of these is my own: Michael C. Weber, "The Translating and Adapting of al-Farabi's *Kitāb Iḥṣa'* alʿulūm in Spain," (Ph. D. diss., Boston University, 1996), which has a translation of Gundisalvus's text as the Appendix. The best text of the Arabic is a critical edition published by Uthman Amin, ed., *Alfarabi*: Kitāb Iḥṣa' al ʿulūm (Cairo, 1931).

[5]Ṣāʿid al-Andalusi, 50.

different individuals who had widely differing styles of translating. Given that we are familiar with each of their tendencies as a translator we can not only compare each man's work with the original Arabic, but we can also compare the two Latin translations and so infer something of each man's knowledge of the subjects under discussion.

So, what curriculum does al-Farabi offer? He believed a Muslim seeking after education first needed knowledge of language; second, what he simply called "Logic"; next the mathematical sciences expanded beyond the Latin *quadrivium*; fourth, the sciences of physics and metaphysics, understood in Aristotelian terms; and finally, in what must be termed the most "Islamic" chapter, one finds a discussion of law, politics, and theology, with the latter stressing the use of reason in defence of belief. In what was decisive for the student, unlike the other texts on the "Divisions of the Sciences," al-Farabi's text listed the ancient books and told where within them one could find the subject under discussion. In short, this text was a guide to the authorities of the past. But it was more than that. Of all the texts discussing the divisions of the sciences that survived into the twelfth century, al-Farabi's had a pedagogical intent: namely, to guide students from the easier subject to the harder until the student had become the type of thinker who "knew with certainty." Thus, al-Farabi presents a series of basic uses for his book: his reader would come to know what is in each branch of knowledge, know the utility of each branch and which branch to use to what end, learn how to discriminate between the branches, and, in the end, all of this would help him to distinguish the truly learned man from the phoney imitator. Most certainly, its main function in the Latin West (and in the Islamic world) was to provide a reading list to the basic student in philosophy. Whether the student recognised it or not, he was being led onto progressively higher and more speculative realms of thought. Unlike other popular texts from the Islamic world, Ibn Sina's *Shifā* and al-Ghazali's *Maqāṣid*, I believe that al-Farabi's book was the most important of these curricular guides in the Christian world because of its wider dissemination. Consequently, it is the reading and the translating of the works that al-Farabi recommends that became the cornerstone of the transformation of a liberal arts education, moving it beyond the *trivium* and through the *quadrivium*, motivating students to be *philosophi* instead of *scholares*.

In order to study the influence of al-Farabi, I want to begin by looking at the first level of appropriation of his ideas, that which his two translators made by focusing on the mathematical sciences. Second, I want to consider the effect of the translations in providing the curricular guidance to students, especially at Oxford in its early period.

When we turn to the chapter on the "Mathematical Sciences," *(fī ʿilm al-taʿālīm)* or the *sciencia doctrinalis* in Latin, we find that al-Farabi has significantly expanded the curriculum of the "mathematical sciences" beyond the old *quadrivium*, which had included music, astronomy and astrology. He adds optics, statistics, and the science of the making of mechanical devices to the base of arithmetic and geometry. Al-Farabi tends to divide the seven sciences that make up this division of human knowledge into two groups: the theoretical and the practical, contrary to his presentations of the other sciences. For him, the theoretical is the more difficult and the purer form of knowledge. In his neo-Platonic epistemology, it is by the act of the speculative, theoretical intellect that a person comes to knowledge of the intelligibles. The distinction between theoretical and practical is not simply convenient or heuristic: it represents the basic division in man's rational faculty.[6] The reason for this seems to be that it is with the mathematical sciences that one begins to lift the mind to pure rationality. Because mathematical (especially geometrical) realities can be represented in nature, they are concrete examples of the pure, speculative ideas that stand behind them. Hence, mathematical thought is the first step to higher level cognition.[7] Such thinking is the chief function of the soul.[8] In *Table I* I have presented the divisions of the mathematical sciences as al-Farabi enumerated them.

In his discussion of arithmetic, al-Farabi treats the subject in five short paragraphs. As was mentioned above, he divides the science into theoretical and practical and devotes most of his discussion to the theoretical. Interestingly, al-Farabi recommended no textbook for this study, probably because at the end of the discussion of geometry he says clearly that Euclid's *Elements* is the place where "one finds the principles of geometry and arithmetic." When Gundisalvus finished his initial discussion of the differences between the practical and theoretical, he tells the reader that everything about arithmetic could be easily learned from the *Arithmetica* of Nichomachus (of Gerasa). This was a well-known text, *The Introduction to Arithmetic*, which had been translated into Latin in the Roman Empire, recommended by Cassiodorus,

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[6]See Osmin B. Baker,"The Classification of the Sciences in Islamic Intellectual History," (Ph. D. diss., Temple University, 1989): 83.

[7]See Muhammad Ar-Rabe, "Muslim Philosophers' Classifications of the Sciences: al-Kindi, al-Farabi, al-Ghasali, and Ibn Khaldun," (Ph. D. diss., Harvard University, 1984): 86-97. He has found many places in al-Farabi's works where he makes this implied pedagogical priority explicitly.

[8]See on this Fuad S. Haddad, *Alfarabi's Theory of Communication*, (Beirut,1989), 173.

and adapted by Boethius in his *De Institutione Arithmetica*.[9] It is a work that Julio Samsó has characterised as a book "one would expect to be known in al-Andalus in the second half of the fourth/tenth century."[10] The Andalusi tradition preserved by Ṣāʿid enumerates Nichomachus of Gerasa as one of the fine men who deserve to be called "philosophers of Greece," even though Ṣāʿid misidentifies him as the father of Aristotle.[11] This addition indicates that Gundisalvus was aware of other textbooks beyond what al-Farabi mentioned. Moreover, Gundisalvus returns to practical arithmetic at the end of his section on arithmetic and discusses the commercial uses of math, known in Arabic as the al-ḥisāb wa-'l-muʿāmalāt, the arithmetic of commerce. Such works were not only common in al-Andalus but earlier in the twelfth century John of Seville had translated one of these into Latin. In it, Ibn al-Samh (d. 1035) actually quoted al-Khwarizmi as well as Nicomachus and Euclid. As Samsò describes its contents, it "ends with a long collection of practical problems which might be of interest to a merchant."[12] Thus we find one translator, Gundisalvus, describing additions to al-Farabi's list of authorities using the very books which are known now to have been in al-Andalus at that time. Gerard of Cremona characteristically only exactly reproduces the Arabic in Latin.

After discussing arithmetic, al-Farabi begins his discussion of geometry. In presenting this science, curiously neither al-Farabi nor his translators provided a textbook-style definition of geometry, although Gundisalvus knew one and utilised it in his *De divisione philosophiae* (a work he wrote later by cutting and pasting together numerous additional Arabic sources with the western traditions of Boethius and Isidore of Seville); however, there was little that he might have turned to in Latin as an alternative to the Arabic tradition on this subject. Of course, the main division of geometry is between theoretical and practical. Both translators begin as al-Farabi does with the discussion of the practical. Al-Farabi had begun his discussion with a con-

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[9]Cf. *Oxford Classical Dictionary*, 733-34.

[10]Julio Samsó, "The Exact Sciences in al-Andalus," in *The Legacy of Muslim Spain*, ed. S. K. Jayyusi (Leiden, 1991), 953.

[11]*Science in the Medieval World*, 21. N.b., in the translation of Salem and Kumar they have used "Nicomack" as the form of the name, a maddening characteristic of this translation of the *Tabaqat*. See, in this regard, C. Burnett's review in *Historia Scientiarum* 3.2 (1993): 157-158.

[12]Samsó, "The Exact Sciences," 953. He refers the interested reader to J. Sesiano, "Le Liber mahamaleth, un traité mathématique latin composé au XIIe siècle en Espagne;" *Actes du premier colloque internationale d'Alger sur l'histoire des mathématiques arabes* (Algiers, 1988): 69-98.

sideration of the function of lines, planes, and solids as they appear in various materials (wood, iron, walls, land), as made by various artisans (carpenter, smiths, masons, surveyors).

While his translators reproduce this main division of the chapter, they had some difficulty translating this section because there appears to have been no standard Latin terminology available to them describing this particular science. I, for one, am not sure the basic concepts of geometry were even clear to Gerard of Cremona; for while he remained the *fides interpres*, woodenly literal in rendering the Arabic into barely comprehensible Latin, some of his mistakes would seem to indicate that he really didn't grasp the relationship of the elements of geometry to the rest of science. Dominicus Gundisalvus, on the other hand, desired to add to al-Farabi's text material that he knew from other sources. For example, instead of beginning straight away with al-Farabi's discussion of practical, applied geometry, Gundisalvus detours into a terminological presentation trying to explain the three types of land measurement found in geometry. These three modes of measure he called height measure, measure in a plane, and depth measure (Latin: *altimetria, planimetria,et profundimetria*). Some have felt that this terminology was derived form Hugh of St.Victor's *Didascalion.*[13] However, the terminology is not an exact match. It is more likely that it derives from an Arabic source.[14]

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[13]The relevant passage is Book 2, Chs. 13 and 78 in Taylor's translation of the *Didascalion* (New York, 1962). Hugh calls the third type of measure *cosmimetria,* the term preserved in the *De divisione philosophiae* where Gundisalvus changed to that term while he copied most of his own translation of this chapter of the *De scientiis*. There are a couple of possible explanations for the alteration: it is not likely that it is a variant on any work of Hugh's, for even in his earlier geometry text, *Geometrica practica* he uses the same triad. See Roger Baron, "Notes sur les variations au XIIe siècle de la Triad Géométrique Altimetria, Planimetria, Cosmimetria," *Isis* 48 (1957): 31. It could be taken from an Arabic source that they both had consulted. That there was such an Arabic text (so far unidentified) is clear from the work of William of Conches; see Taylor, notes 52 and 53 to Chapter 2 of the *Didascalion,* 203.

[14]We know that both Gundisalvus and Gerard were aware of al-Nayrizi's (Latin: Anaritus) *Commentary upon Euclid.* Interestingly, Al-Nayrizi wrote another work entitled, *On the Knowledge of Instruments by Means of Which We May Know the Distances of Objects Raised up in the Air or Set up on the Ground and the Depths of Valleys and Wells and the Width of Rivers (Risala fī Maʿrifat alat yu ʿlamu biha ab ʿad al-ashya ash-shahisa fi-'l-hawa' wa-'l-lati ʿala basit al-ard wa aqwar al-audiya wa-'l-ahar wa-ʿurud al-anhar,*

Referred to by A. I. Sabra, *Dictionary of Scientific Biography,* X, 5-6; cf. s. v. "Al-Nayrizi," *Encyclopedia of Islam* VII: 1050) .

The contents of such a work would correspond fairly exactly with the three types of measurement described in *De scientiis,* height, depth, and breadth, and seems to be a closer correspondence to what Gundisalvus wrote than Hugh's text. I cannot say for certain that Al-Nayrizi was the source for the terminology Gundisalvus introduced into

The discussion of the second portion, theoretical geometry, is straightforward, noting that this subject treats lines, planes, figures, and solids in an absolute sense, which is to say, regardless of their embodied material. This whole discussion threw off Gerard of Cremona; as he translated this section, he failed to recognise the reflexive Arabic construction and mistook one form of an Arabic verb for another (in fairness to him, an easy mistake to make). In the end, however, he finishes by producing nonsense in Latin because he did not recognise some elementary terminology. For example, in explaining the subject matter of this section al-Farabi had written, *wayataṣuru fī nasifi al-khuṭūṭ bi-ʾl-wajhi al-ʿām*: "Lines are conceived on their own in the common manner."[15] Gerard renders *fī nafsihi* as "*in anima sua*". If we wished to be apologetic, this might be a possible rendering; *anima* could mean "essence." However, in this context, he stretches the meaning of *anima* beyond its bearing; "essence" is not implied by the Arabic for the *fī nafsihi* is merely reflexive. Gerard knew that the primary sense of the word also meant "soul" and somehow here he must be using *anima* in that way even though it is nonsensical; this is the result of translating word-for-word, his *modus operandi*. This is a translating error that he makes several times in this same paragraph. Similarly, his choice of the verb *curo, curare* to translate the third form of the Arabic *(balā)* in the next sentence (which reads, "which does not take into consideration within which body they exist"), is barely adequate. While *curare* can mean "to pay attention to" I don't think that this is what Gerard has in mind. One of the meanings of the Arabic verb is, "to care for or be concerned about," but here it must mean "to take into consideration," for al-Farabi's point is that in whatever matter a geometrical form is found, that material does not effect the study of the form. While not entirely nonsense, and the careful Latin reader could make a certain amount of sense of this, the meaning is certainly obscured and does not reproduce

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al-Farabi's discussion because I have not been able to ascertain the history of the translation of that work. The Arabic exists only in manuscript in Istanbul. However, it certainly sounds like a very close correspondence. Lemay has noticed that the identity of one book translated by Gerard, called in Latin only *Liber de practica geometrie*, remains obscure; Michael McVaugh has suggested that this might be a text of al-Karaji known as *De mensuratione terrarum* (see Richard Lemay, s.v. "Gerard of Cremona," *Dictionary of Scientific Biography* 16: 177). Lemay further notes that the incipit doesn't match any known work of this title but has not checked it against al-Nayrizi's book; hence, the identification remains uncertain. I hope to investigate this further in the future.

[15]Al-Farabi, Catálogo, .57x .

what al-Farabi meant. Al-Farabi's whole point is that in whatever matter a geometrical form is found, that material does not effect the study of the form. Gundisalvus simply summarises the whole section by saying that theoretical geometry only considers the various geometrical forms "absolutely, without any material." As Gerard translates it, one is led to think that al-Farabi believed that geometrical forms are sensate, having souls and caring what kind of material they are embodied in!

The real test of any translator is technical terminology. In this section there are two difficult terms, neither of which was easily understood. First, in discussing the correspondences and equivalencies of geometric figures, we find the term *surdus*. Surds are, technically, "a sum with one or more irrational indicated roots as addends. Sometimes used for an irrational number."[16] It is in this latter sense that our translators use the term. Second, in a list of three dimensional figures we find "*cubas, pyramides, speras, columnas, serratilia, pinealia.*"[17] All of these are clear except for *serratilia*. From its root this must mean something like, "small sawn object." It is not in any Latin dictionary but it stands for the Arabic term "manshūrāt," which means "prism."[18] Once again, the Latin term reflects a practice of translation according to root as, ironically, does the Arabic word that was used to represent the Greek "*prisma*"; for that noun is derived from the verb, "to saw", and means something sawn. *Manshūrāt* is its literal grammatical equivalent. However, the standard Latin term was the transliteration, *prisma*, which had been used by Capella. Fortunately, we have another twelfth century text concerned with rhythomachy which also uses this term.[19] While it doesn't include a definition, the text makes it clear that *serratilia* stands for the three dimensional object associated with a triangle. Charles Burnett, who has been studying this text,

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[16]*Mathematics Dictionary*, ed., James and Beckenbock (New York, 1968) ad loc. 353. Tummers noted that Gerard is probably responsible for the introduction of this term into the Latin scientific vocabulary in the latter sense. Characteristically, this is a literal rendering of the Arabic *ṣamm* which means in its root "to be silent, be deaf' just like the Latin *surdus;* the proper term is *jadhr* aṣamm the plural of which is *ṣam;* the origin of this term is not to be found in the Greek.

[17]*De Scientiis*, 91; *Catalogo* (Gerard) 147, (al-Farabi) 85.

[18]Both Hans Wehr and J. G. Hava, Al-Fara'id, *Arabic-English Dictionary* 5th ed. (Beruit, 1982) have this meaning. Curiously, in Kazimirski's *Dictionnaire Arabe-Français* (Paris, n.d.): 2:1260, he notes the Latin equivalent *cauterium serratum*. I am indebted to Herbert Mason for this reference.

[19]Cambridge, Trinity College MS R. 15.16, ff. 61v-62r. Burnett is publishing it with a commentary in a forthcoming number of *Viator*. Again, he has kindly provided me with his accepted manuscript.

believes that the term was probably coined in Spain and means "a triangular base pyramid" because there are drawings of just such objects in other manuscripts and, "it would be natural for Spanish translators to use a word for the equivalent Latin root, especially since *serra* meant a mountain range, which has precisely the shape of an elongated prism."[20] It seems likely to me that Gerard probably coined this term as is also likely to be the case with *surdus*.

After carefully comparing these two translations with the Arabic original and the other geometrical texts available in the Latin West c. 1180 it is clear to me that most of the content of this chapter was new and unfamiliar to the translators. There was no established technical terminology and even relatively simple descriptions of theoretical geometry could lead to confusion in the mind of one of the two foremost translators of Arabic texts of the twelfth century. In short, Gerard especially appears to be unprepared by his previous training and experience to comprehend the detail of what al-Farabi had to say on this little-known subject.

In the remainder of the sections on mathematical sciences, Gerard and Gundisalvus are remarkably similar in their translations. In the Latin tradition, they were familiar with music and astronomy as components of the *quadrivium*; however, they had utterly no familiarity with optics, statics, and the science that they ultimately termed "*ingenium*," the "making of mechanical devices." Among all of them, there is only one significant addition, one revealing error, and one enduring terminological exchange. This seems to indicate that there was little else that the translators had at hand on these sciences.

In the science of optics, there is little difference in the two translations. Other than Gundisalvus' citing of Euclid as an authority in the discussion of the relations of geometry to optics, he makes no other additions to al-Farabi and only leaves out small sections that probably appeared to be redundant. Of all the chapters in these texts, this one is the most similar in the two translations. This may be because this was the only text Gundisalvus knew on optics and he had no other material to add. Even the usually expanded text of the *De divisione philosophiae* reproduces this section *verbatim*, including the figures, with only two insignificant changes.

On astronomy we find a curious exchange in terminology by the translators, and one which has endured. Al-Farabi divided the science

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[20]Personal correspondence with me, 2 and 3 March 1995. One strong indication that Burnett is correct is in the *Real academia diccionario* which does list *serratilia* as a medieval Spanish word; however, its meaning is given as *cordillera*, "a chain of mountains," which explains the derivation.

of the stars up into two great divisions (which he did not designate in this case as "theoretical" and "practical"). However, as he usually treats the practical first and the theoretical second, it would not be too far afield to see him encouraging us to see astrology as the practical (i.e., the lower science) and astronomy as the theoretical. The first science is the science of astrological "judgements": the knowledge of what has been, what is and what will be. The second is the "mathematical science" of the stars, the study of the heavens and the earth. While we would call the first "astrology" and the second "astronomy," Gundisalvus, who adds the titles to al-Farabi's definitions, reverses them. The confusion of these two terms did not end with Gundisalvus.Vincent of Beauvais, in his *Speculum doctrinale*, reproduces much of Gundisalvus' translation, though he attributes it to al-Farabi. In section XVIII.46 he presents the science of the stars, preserving Gundisalvus' nomenclature, and still refers to what should be called "astrology" as "astronomy" and vice versa. More significantly, St. Thomas Aquinas, who certainly was not unacquainted with the Aristotelian scientific traditions of antiquity, also reproduces this terminology. In a general listing of the liberal arts in his *Commentary on the de Trinitate of Boethius*, written between 1255 and 1259, he uses the term *astrologia* as the general term for astronomy.[21] The editor and translator of this text notes that this is St. Thomas' usual terminology for that science "whose subject is the heavens and the celestial bodies."[22] In St. Thomas' case, he certainly was widely read and could have derived the proper terminology from many sources, but he used this oft derided error of Gundisalvus as his standard. Perhaps the great Doctor respects the Toledan's nomenclature because of the reputation of Spain, and Toledo in particular, as the place where these "black arts" were well-known.

Finally, in the section on music, there is a curious error of translation. The definition of the fourth part of theoretical music is only one sentence long. It simply says that this part of music teaches about the "classes of natural rhythms" or "iqāᶜat." Now, all of the Latin translations show the same error and translate "rhythms" as "*casuum*"; "cases" or "occurrences" in Medieval Latin. "The classes of natural cases" or "occurrences"? This makes no sense. What appears to me to have occurred is either another example of either translating according to roots or, as is more likely, mishearing in the process of translating. The root of the Arabic verb "waqaᶜa" has the same root meanings as *casus* (from *cado*). The root of *"iqaᶜat"* is weak in the first root, and so may easily

[21]*The Divisions and Methods of the Sciences*, ed. and trans. A. Maurer, (Toronto, 1986), 44.
[22]Ibid., 44 n. 24, quoting another work of St. Thomas in III *Metaphysica* lect. 7, n. 41

have been misheard as *"ikhwāt"* (from the root *"khawā"* "to be empty"). Otherwise, I can think of no explanation for the an intentional change of terms. In either case, it never seems to have bothered either translator that they had produced something close to nonsense nor any other Latin writer who reproduced this text.

We may be curious as to why this lack of concern for the plain sense of the text seems to have escaped not only the original translators but others who followed and read their manuscripts. It seems to me that the answer lies in the larger framework of what must have been an exciting enterprise: the scholars of Gerard's and Gundisalvus' time were pioneers, not perfecters, and it appears to me that they endeavoured to get as much Arabic material as possible into Latin, even if they understood it imperfectly. Several passages, especially in Gerard's work, look as though they received no editing at all. For example, in the chapter on grammar he consistently merely transliterates technical terminology when even a brief consultation with a grammarian would have yielded the proper Latin equivalent. This was in spite of the fact that, as we know, there was a *magister scholarum* in Toledo, who would have taught grammar at the same time Gerard was translating there. There appears to have been no interest in producing a "finished" translation. The book *per se* appears to have been the significant end-product. As Guy Beaujouan has described one aspect of the influence of the translation movement, "Change took place exactly to the extent that twelfth-century humanism attached more importance to the form of texts. The great era of translation began with Adelard of Bath, and, in the *quadrivium*, was marked by an increased emphasis upon the use of books."[23] And this book was, even with the errors and transliterations, a new and important source for learning the science of the Arabs. It was exactly this kind of new book, full of the knowledge of the Arabs, that Daniel of Morley wished to take back to England and that Petrus Alfonsi advertised that he could teach to the peripatetics of France.[24] This new knowledge slowly changed the face of higher education.[25] For such change to come to pass, texts were the necessary ingredient. Here Charles Burnett has observed, the *Enumeration* "provided a template for Gerard on which to pattern the programme of

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[23]Guy Beaujouan, "The Transformation of the Quadrivium," in *Renaissance and Renewal*, eds. Benson, Constable and Latham, 464-465.

[24]Daniel's text is in Karl Sudhoff, ed., *Archiv fur des Geschichte der Naturwissenschaften und der Technik* V. 8, 1-41 while Alfonsi's is found in John Tolan, *Petrus Alfonsi and his Medieval Readers* (Gainesville, 1993).

[25]See Gillian R. Evans, "The Influence of Quadrivium Studies in the Eleventh- and Twelfth-century Schools," *Journal of Medieval History* 1 (1975): 151-164.

his own translations,"[26] which not only he followed but also seemed to guide many of the Toledan translators who came after him. This is especially true in the philosophical and natural science sections of the work. Consequently, on the question of al-Farabi's curricular influence, we must remember that the scholars in the Latin West did not read the Arabic original, but rather got their recommendations from "*Alfarabius*", which meant "Al-Farabi as Gundisalvus had translated him". Of course this is how Vincent of Beauvais presents Gundisalvus' translation; but even a more disciplined scholar like Roger Bacon thought the *De scientiis* to have been written by al-Farabi. Consequently, when we turn to consider the influence of the mathematical sciences, it is the work of Gundisalvus/al-Farabi that we must consider. In mathematics he had recommended Euclid's*Elements* and the books the Latins called *al-muchabala*, (properly *"al-muʿāmalāt"* in Arabic, or "books of practical mathematics"), and Nichomachus' *Arithmetic*. Gerard translated sections of the first and at least two works on *muchabala*[27] even though these had been translated earlier in the twelfth century by John of Seville and the text of Euclid had been translated by Adelard of Bath.[28] Nichomachus' book on arithmetic had long been available and was not in need of translation by the end of the century. It is possible that Gerard was unaware of the other two translations, but this is doubtful. In addition, among his seventeen translations of geometrical texts Gerard had also translated al-Nayrizi's *Commentary on Euclid*, which included one text called simply, "On the Measurement of the Earth." So, it is fair to call Gerard the sponsor of the revival of Arabic mathematics in the Latin West, even if he was not always so recognised. In music, H. G. Farmer zealously documented the influence of both al-Farabi's *Great Book on Music* and the *Enumeration of the Sciences*.[29] In the other branches of the *quadrivium*, Vincent's *Speculum doctrinale* was widely read, quoting *Alfarabius* at length. Further evidence of influence is to be found in lists of textbooks used in the study of the *quadrivium* after 1200: Euclid is present, sometimes the *muchabala* presented (just as it is in the Arabic tradition often accompanying algebra), and often other composite works such as Sacrobosco, based upon Arabic sources in geometry and arithmetic.

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[26]Charles S. F. Burnett, "Translating Activity in Medieval Spain", *The Legacy of Muslim Spain*, 1045.

[27]Lemay, 187; See also his expanded list of Gerard's translations, 176-190.

[28]A. C. Crombie, *Augustine to Galileo: The History of Science A. D. 400-1650* (London, 1952), 23-30 has a nice chart of the sources of western science. It is a bit dated now.

[29]See Henry George Farmer, "The Influence of al-Farabi's Ihsaʾ al-ʿulum," *Journal of the Royal Asiatic Society* (1932): 561-592 and "Ihsa' al-ʿulum," *JRAS* (1933):906-909.

One very early curricular list is that which Haskins believed to have been made by Alexander Neckam (1157-1217), a friend of the translator Alfred of Sarashel who worked in Spain, and who was a younger contemporary of the two translators with whom we are concerned. It contained many of the new books recommended by al-Farabi. Neckam studied and taught in England and Paris from 1180 up to his death and was one of the first scholars to be influenced by the new translations. In the quadrivium he recommends Euclid on arithmetic, Boethius on Music, Euclid again on geometry, and the Ptolemaic Tables along with al-Farghani for astronomy.[30] A much more important work influenced by Gundisalvus' translation of al-Farabi's *Enumeration*, though to a lesser extent, was Robert Kilwardby's *De ortu scientiarum*, which owes nothing to the Latin translation of an Arabic *opusculum* of the same name which was also believed to have stemmed from al-Farabi.[31] This text, written in 1247-1248, has been called the "greatest example of the genre" of divisions of the sciences and is credited with bringing the production of such texts to a halt.[32] Interestingly, the very first quotation —which is the very first sentence— is a précis of Gundisalvus' prologue to the *De divisione philosophiae*, which in turn is loosely modelled upon his own prologue of the *De scientiis*. This quotation even preserves the exemplum Gundisalvus had used, though it doesn't acknowledge him as the source.[33] This indicates to me that Kilwardby had Gundisalvus text in front of him as he began his own work. At several points in his text, Kilwardby quotes Gundisalvus' definitions or distinction in the purposes or boundaries of the sciences. These citations run the gamut, but are particularly used for the sciences of the *quadrivium*. Kilwardby often approved of Gundisalvus' definition in distinction to the other authorities he utilised. Thus, by the time Kilwardby was writing, when the whole Aristotelian corpus was available and Aristotle's "new" texts had already been banned and reinstated at the University of Paris twice, Gundisalvus/al-Farabi was still an authority on the organisation and definitions of the sciences, perhaps the first authority to whom a scholar would turn. In the development of formal courses of study in the thirteenth century, as

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30 Charles Homer Haskins, "A List of Text Books from the Close of the Twelfth Century," in *History of Medieval Science*, 360.

31 Kilwardby, *De ortu scientiarum* ed. Albert Judy (London, 1976), 9.

32 Nancy Spatz, "Divisions of the Sciences in University Master's Inception Speeches," unpublished paper delivered at the American Historical Association Annual Meeting, January 1994, San Francisco, 2. I wish to thank her for providing me with a copy of the paper.

33 Kilwardby, 9.

Weisheipl noted, "it is not easy to obtain a full picture of the normal course of studies in the medieval university. Our information is particularly meagre concerning the faculty of arts."[34] But, to be graduated from Oxford, a student had to have read not only the old canon, but also the six books of Euclid's *Elements*, the *Algorismus* (i.e. al-Khwarizmi), the *Computus*, and the *De sphaerae* of Sacrobosco, which was derived from Arabic texts. These were considered as accepted standards in 1268. For our purposes, though, the expanded arts —optics, statistics, tracts on quadrants and the astrolabe— and the Alfonsine Tables were represented at Oxford as an important part of the *quadrivium* that everyone needed to be a master.[35] When one turns to consider these new branches of the quadrivium —the truly new elements of the curriculum without roots in the Latin West— the readings called for appear as if they were read straight out of the *Enumeration* in the version preserved in the *De scientiis*. Perhaps more important still, Kilwardby "paid special attention to the relation of the mathematical disciplines to physics."[36] Crombie, who notes this influence, goes on to say that the sharp Aristotelian distinction between the two disciplines "slowly came to be doubted. Indeed, from one point of view, the whole history of European science from the twelfth to the seventeenth century can be regarded as the gradual penetration of mathematics... into fields previously believed to be the exclusive preserve of 'physics.'"[37] While he recognises this as stemming from Kilwardby, he doesn't seem to recognise the influence of al-Farabi, through Gundisalvus, upon Kilwardby. As al-Farabi taught clearly, practical geometry was, for all intents and purposes, engineering. This is made clear not only in the opening of the geometry chapter but is explicitly stated at the start of the chapter on the science of mechanics. In George Saliba's translation, "The science of mechanics is the knowledge of the procedure by which one applies all that was proven to exist in the mathematical sciences ... and the act of locating and establishing it in actuality."[38]

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[34]James Weisheipl, "Curriculum of the faculty of Arts at Oxford in the Early fourteenth century" *Mediaeval Studies* 26 (1961): 145.

[35]Ibid., 168-176 provides an extensive listing of subjects and the texts derived from the "Ancient Statutes of the University of Oxford." He does not say what text of al-Khwarizmi was being referred to.

[36]Crombie, 51.

[37]Ibid., 52.

[38]George Saliba, "The Function of Mechanical Devices in Medieval Islamic Science," *Annals of the New York Academy of Sciences*, 441 (1985): 145. This includes a translation of the section of al-Farabi's Book Three on the ʿilm al-hiyal.

Thus, while it is difficult to prove the precise and direct influence of al-Farabi's *Enumeration*, we can see its wider influence in both the divisions of the sciences and the reform of the curriculum as practised at Oxford in the thirteenth century and in earlier curricular lists created by Englishmen for the other fields of the mathematical sciences. The very interest in the divisions of the sciences, while started by Hugh of St. Victor, moved away from his basic distinction and adopted those of the Muslim philosophers instead. Inclusion of the new subjects of optics and statistics and requiring the reading of tracts on the astrolabe and quadrants as well as the Alfonsine Tables indicate the influence of al-Farabi's divisions, if not his exact curricular recommendations; but most important of all is his conception of the relations of the mathematical to the physical sciences.

In conclusion, then, even though his translators understood him imperfectly and had a limited command of the subject matter he laid out, they understood the importance of expanding the *quadrivium* in new sciences by exploring new texts that al-Farabi made known to them. It appears that they dedicated their lives to this pursuit and ultimately succeeded in introducing new knowledge so that, as Gundisalvus himself put it in one of his prefaces, a work hitherto unknown to Latin readers, since it was hidden in Greek and Arabic libraries, has now, by the grace of God and at the cost of immense labour, been made available to the Latin world so that the faithful, who toil assiduously for the good of their souls, may know what to think about it, no longer through faith alone but also through reason.[39]

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[39]Preface to de *Anima*, quoted and translated by Jean Jolivet, "The Arabic Inheritance" in *Renaissance and Renewal*, eds. Benson, Constable and Latham: 142.