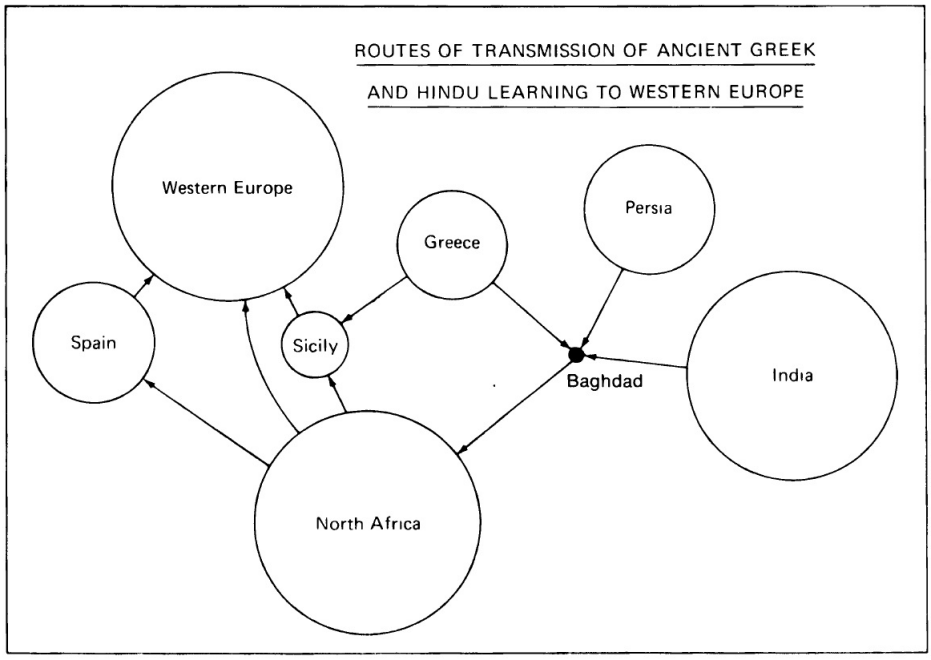
8.2. The Period of Transmission

Note. In this section we consider the transmission of the Greek classics in science and mathematics as they filtered into western Europe from the Arabic cultures that had preserved them starting around year 1000. We discussed this in Section 1.9. The Hindu-Arabic Numeral System (see Note 1.9.F and its map of Arabic world in the 7th to the 9th century).

Note. The transmission took place through translations made by Christian scholars traveling to the Arabic centers of learning, such as Gerbert of Aurillac (circa 946–May 12, 1003) as described in the previous section. "The translations were mostly from Arabic to Latin, but there were also some from Hebrew to Latin and from Arabic to Hebrew and even some from Greek to Latin" (Eves, page 260).

Note. The Romans incorporated the city of Toledo (in central Spain, near modern-day Madrid) into the Roman Empire around 200 BCE after a battle with local Celtic tribes. The Visigoths (a Germanic people living in the Roman Empire of the time) took control of Toledo around the mid 6th century, until the Moors (Muslim inhabitants of northwestern Africa and the region of modern-day Spain) conquered the Iberian peninsula in the early 700s. After a several-year siege Alfonso VI, a king of several kingdoms on the Iberian peninsula, on May 24, 1085 entered the city of Toledo with his Christian forces. This was followed by an influx of Christian scholars interested in gaining the Arabic (or "Muslim") knowledge there. Other areas of the Iberian peninsula fell from control by the Moors and additional

Christian scholars moved in. As a result, the 12th century became "a century of translators" in the history of mathematics (Eves, page 260). The following figure schematically illustrates the flow of knowledge into western Europe.



Note 8.2.A. Adelard of Bath (1075–1160) was an English philosopher who translated Arabic mathematical works into Latin. Details of Adelard's life are somewhat speculative. He studied in France, and then traveled around Europe, including Italy, Sicily, and Turkey. There is no record of him visiting Spain, but it is thought that he must have visited at some point in order to have access to the Arabic texts in Spain which he translated. The records of the city of Bath (England) indicate that he returned there in 1130. Adelard translated Euclid's *Elements* from Arabic into Latin twice (possible three times). One version is a translation of the 12 books of Euclid along with the two additional books written by Hypsicles. This version seems to be based on one of al-Hajjaj's Arabic translations from Greek. This is the oldest surviving Latin translation of Euclid's *Elements*. A second version is

significantly different from the other version and only provides outlines of proofs. A third version, debatably written by Adelard, is a commentary on the *Elements* rather than a translation of the original text. He wrote books on the abacus, astrolabe, and arithmetic. His earliest arithmetic book was written before he studied Arabic arithmetic and is based on the work of Boethius (we discussed Boethius in Section 8.1. "The Dark Ages" (The Middle Ages)). Another arithmetic book attributed to Adelard (though this is not universally accepted) is strongly influenced by Arabic ideas and part of it is based on the Indian methods as presented in Arab writings. It also covers geometry (presented in a completely Greek style), music, and astronomy (the astronomy part if Arabic in style). It is thought that his may be based on a book of al-Khwarizmi which is lost.

Another work attributed to Adelard is a translation of al-Khwarizmi's astronomical tables, which were the first Latin translations of Arabic tables using the Indian symbols. Adelard's philosophical writings include *De Eodem et Diverso* ("On the Same and the Different"), modelled on Boethius' *Consolation of Philosophy*, and treatise on hawking called *De Avibus Tractatus* ("Treatise on Birds") on hawking. His best known philosophical work is *Questiones Naturales* ("Questions on Natural

Science"), in which he sets out seventy-six questions, in a presentation similar to Plato's *Dialogues*, about meteorology and natural science. This work was heavily used in schools of the 13th century. These historical notes and the image above are from the MacTutor biography webpage of Adelard (accessed 6/19/2023).

Note 8.2.B. Plato of Tivoli (also known as Plato Tiburtinis), whose birth and death dates seem unknown, was a 12th century Italian mathematician, astronomer, and translator. He was apparently the first to translate information on the astrolabe from Arabic into Latin when he translated *De usu astrolabii* of Maslama al-Majriti (950–1007). He translated Claudius Ptolemy's (circa 100 CE–circa 170 CE) *Tetrabiblos* (a book on astrology), the astronomical works of al-Battani (circa 858–929; these translations were influential on the development of science and astronomy in Europe), Theodosius of Bithynia's (circa 160 BCE–circa 90 BCE) *Sphaerics* (a book on the geometry of the sphere intended to provide a mathematical background for astronomy, though it contains no sperical trigonmetry), and Abraham bar Hiyya's (or "bar Chiia," also known as Abraham Savasorda; circa 1070–circa 1040) *Liber Embadorum* ("Practical Geometry," written in Hebrew) which included an complete treatment of the quadratic equation. This later material influenced the work of Leonardo of Pisa (aka. "Fibonacci"). In fact, Abraham bar Hiyya probably collaborated with Plato of Trivoli on the translation of *Liber Embadorum* into Latin. Bar Hiyya himself also translated a number of works, several on astrology but one on mathematics (the original author of which is unknown), *Liber Augmenti et Diminutionis* ("The Book of Increase and Decrease"). This history is based on the Wikipedia webpages on Plato of Tivoli and Abraham bar Hiyya (accessed 6/20/2023).

Note 8.2.C. Gherard of Cremona (or "Gerard"; 1114–1187) was an Italian mathematician who worked in Spain translating mathematical works from Arabic to Latin. Gherard went to Toledo in Spain (perhaps in the 1140s) and stayed there for most of the rest of his life. Over a period of 40 years, he was involved with the translation of around 80 works from Arabic to Latin. He appears to have had assistance and likely employed helpers who were involved with copying and checking manuscripts. He translated straight-up Arabic works, Greek works that had been translated into Arabic, and Arabic commentaries on Greek works. Gherard's priority was producing a Latin translation of Ptolemy's (circa 100 CE–circa 170 CE) *Almagest*. He translated this from Arabic and it became the most widely known version in Western Europe, though the ideas it contained became outdated with Nicolaus Copernicus' (February 19, 1473–May 24, 1543) publication of his heliocentric theory in *De revolutionibus orbium coelestium* ("On the Revolutions of the Celestial Spheres") in 1543. There are now translations of *Almagest* from the original Greek (one was written in Sicily around 1160). Other works translated include: Archimedes' *On the Measurement of the Circle*, Aristotle's *On the Heavens*, Euclid's *Elements*, and al-Khwarizmi's algebra book *The Compendious Book on Calculation by Completion and Balancing*.

Note. The location of Sicily (the island at the toe of the "boot" of Italy) in the central Mediterranean put it at the cross road of Western Europe and the Arabic world. It started as a Greek colony, was part of the Roman Empire, was affiliated with Constantinople after the fall of Rome, was held by the Arabs for half of the 9th century, then taken over by the Normans (of northern France). Greek, Arabic, and

Latin were spoke on the island. Communication between Sicily, Constantinople, and Baghdad was common and many Greek and Arabic manuscripts on science and math were imported and translated into Latin. This continued (and was encouraged) by the Kings of Sicily Frederick II (1194–1250) and his son Manfred (1231–1266) (Eves, page 261).

Note. As we'll see in Supplement. Leonardo of Pisa (Fibonacci) and the Liber abbaci, that commercial applications were instrumental in the spread of the Hindu-Arabic numerals through Italy and then the rest of Europe. The first merchants to establish relations with the Arabic world were in the Italian cities of Genoa, Pisa, Venice, Milan, and Florence. This contact required conversion of currencies, calculating prices, calculating taxes, and calculating salaries of workers in different areas. The benefit of the Hindu-Arabic numerals over the widely used Roman numerals became apparent rather quickly (though the spread of their use into the rest of Europe wasn't as fast). Also instrumental in the spread was Spain, where the Arabic influence was greatest in Western Europe (notice again the map of the Arabic world in Section 1.9. The Hindu-Arabic Numeral System ; see Note 1.9.F).

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