Gerbert de Aurillac: A Scientific Light in the Dark Ages

His work and his teaching influenced the European thinkers that followed in the Renaissance.

By Samuel M. Wilson

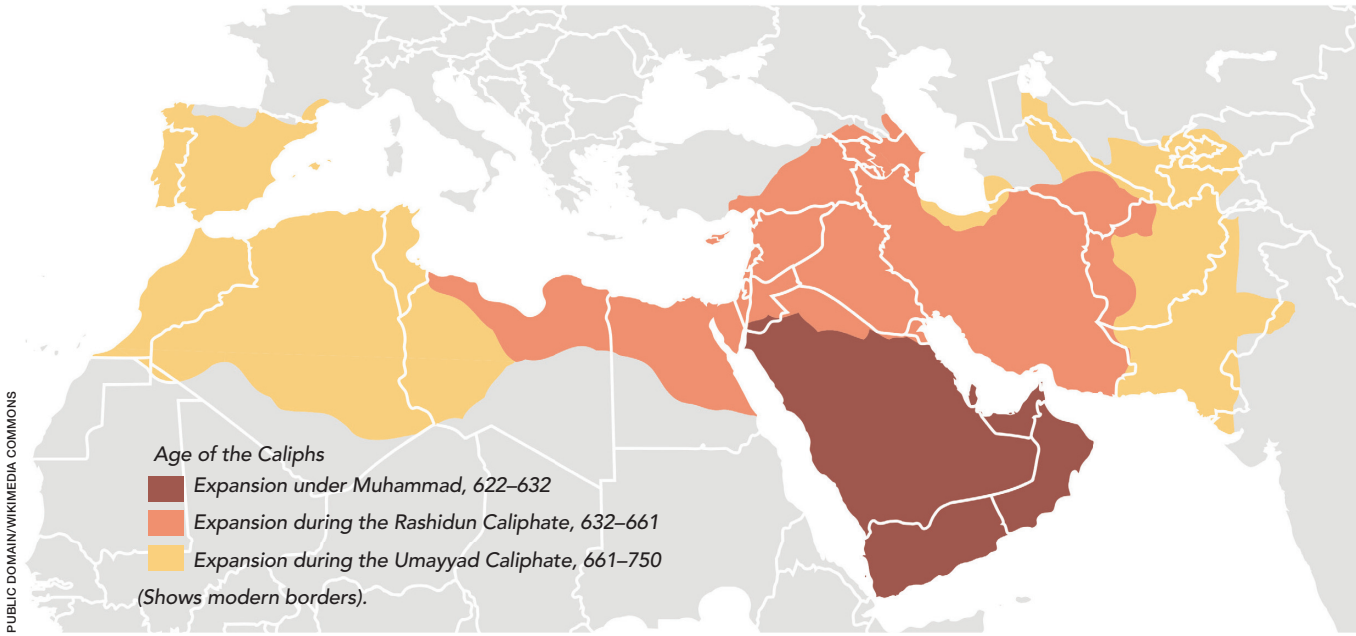
In the year 999 CE, it was rumored that Pope Sylvester II kept a mechanical head in a box, a brass creation that came from the Moors in Islamic Spain. It was said that the Pope could pose simple questions to the brazen head and receive "Yes" or "No" answers. He also was said to have kept a book of spells locked away in the chests that he had brought back from Muslim lands, which afforded him great power and fortune in his life. Accounts from the twelfth and thirteenth centuries had him consorting with demons and calling on dark magical powers. With these supernatural aids, the stories went, a friar from humble beginnings in rural France, Gerbert de Aurillac (c. 947–1003), came to study at the highest centers of learning in Europe. He became an envoy to the Court of the Caliphate of Córdoba and eventually rose to become Archbishop of Reims in France and Abbot of Bobbio, in Italy. He tutored a future king of France, two Holy Roman emperors, and dozens of church and secular leaders, and at the Vatican he was named as the Supreme Pontiff and Vicar of Christ, Pope Sylvester II. He was Pope only a short time, from 999 CE to his death in May 1003, but he represented a change in approach to learning and ecclesiastical knowledge. Gerbert de Aurillac, the man who made this remarkable journey, had more in common with the polymaths and scientists of the Renaissance than with what we might think of as a deeply conservative and theocratic church of the medieval "Dark Ages."

Gerbert de Aurillac's passion for math and science led him to Spain to study, and he ended up influencing the spread of Indo-Arabic numerals and novel methods of mathematical calculation to Europe. However, he was "demonized" and treated as a heretic within a few generations of his death. This shift sheds light on the changes that took place in Europe around the time of the Crusades (roughly 1095–1300 CE), during which time knowledge that came from Islamic sources came to be seen as blasphemous and dangerous.

"Pope Silvester II and the Devil," from a fifteenth-century manuscript of Chronicon pontificum et imperatorum *(Chronicle of the Popes and Emperors)*

Gerbert was born in a little village near Aurillac and was educated in a Benedictine monastery there. Aurillac, in south central France, was a long way from any of the dominant medieval centers. The road distance was 550 kilometers (km) south of Paris, 500 km north of Barcelona, 700 km east of Milan, and over 1,000 km away from Rome. If it was on the way to anywhere, it was between these European centers and the Spanish March, the buffer zone in southeastern Spain between Christian Europe and Muslim-controlled lands in Al-Andalus, or Andalusia.

The real centers of power in 1000 were in Constantinople and Baghdad. There were also states and empires in India, China, and the Americas, but the Islamic world and the Byzantine Empire had a direct and sustained impact on the development of Europe. In the centuries after the death of the Prophet Mohammed (570–632), a series of political caliphates spread from the Arabian Peninsula and Middle East all the way from western India to southern France. United by Islamic religion and the Arabic language, the Umayyid and then Abbasid empires had been in control of most of modern Spain and Portugal for centuries by Gerbert's time. After the Caliphate's armies had spread to within 250 km of Paris in 732, they had fallen back to the southwest. A buffer zone between the two areas had been established between what is now Spain and France, negotiated between Frankish king Charlemagne (c. 747–814) and the Umayyid Emir of Córdoba in 795. Charlemagne's allies during this period of territorial pushing and shoving included the Muslim leaders of kingdoms



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in northern Spain, who preferred to strengthen their ties to France rather than submit to the rulers of Córdoba.

It would be misleading to define the vast Umayyid and Abbasid empires as purely Islamic, because the majority of the population was non-Muslim. Christians and Jews made up about half of the population of Al-Andalus in the tenth century, with people from both groups holding positions in the government of the Caliphate. The intellectual centers in Córdoba and Fez, Morocco, had large numbers of Christian and Jewish scholars. The hotbeds of scientific understanding and research in the Islamic world were Baghdad in the east and Córdoba in the west.

When Gerbert was about seventeen, the Christian ruler of Barcelona, Count Borrell (d. 993), was passing through France and stopped at the monastery at Aurillac, where he was hosted by an abbot named Gerald, who spoke with him on behalf of his ambitious and restless pupil Gerbert. He asked about scholars in Barcelona who would be able to continue Gerbert's education, particularly in science and math, and Borrell assured him there were many. The men arranged for the Count to take Gerbert under his wing and bring him to Andalusia.

More than in Paris or Milan or other medieval towns, scholarship was esteemed on both sides of the border between Christian and Islamic Spain. Manuscripts were being copied, annotated, translated, and passed around from place to place. Gerbert had access to the scriptoria at several monasteries and palaces around Barcelona, more than he had ever seen. At the time, and for the rest of his life, he would correspond with scholars across Europe and Andalusia, trying to obtain copies or access to books on mathematics, philosophy, rhetoric, and astronomy. In the year 984, he wrote to his old abbot, Gerald of Aurillac, asking for an important book in his study and teaching. He wrote, "Abbot Guarin [from the monastery of St. Michel de Cuxa in Andalusia] left you with a little book, *On the Multiplication and Division of Numbers*, written by Joseph the Spaniard, and we both should like a copy of it." It was written by a monk who had studied with Muslim scholars and probably read and spoke Arabic, as most Christian scholars at Córdoba did. This was one of the books that links Gerbert and his teaching with the most advanced mathematics of the Islamic world. Gerbert spent about three years in Andalusia, from 967 to 970. He worked at the monastery at Cuxa, also at an important library at Santa Maria de Ripoll, and in the social and political world of Count Borrell.

METROPOLITAN MUSEUM OF ART

Astrolabe of a Rasulid prince, 'Umar ibn Yusuf ibn 'Umar ibn 'Ali ibn Rasul al-Muzaffari (690 AH/1291 CE)

Back in France his education had consisted of what was known as the "trivium"—the fields of grammar, logic, and rhetoric. As a novice monk, he had been steeped in the theology of the Roman Catholic Church, and studied the Bible in Latin and probably some Greek. When he went to Andalusia, his mission was to study the higher tier of Greco-Roman learning: the "quadrivium," which included the four fields of arithmetic, geometry, music, and astronomy. The quadrivium derived from the organization of education in classical Greece. In *The Republic* (written around 375 BCE), Plato describes the proper education of the philosopher-king, and in addition to the quadrivium discusses some of the other practical areas of knowledge, such as medicine, law, and architecture. Our modern high school and college curriculum has its roots in this tradition. This was also the curriculum in Islamic scholarly centers, where students pursued the "seven streams of wisdom"—the same as those of the trivium and quadrivium.

MUSEUM OF THE HISTORY OF SCIENCE, OXFORD

A spherical astrolabe from medieval Islamic astronomy, c. 1480

Much of this model of the Greco-Roman curriculum, and indeed knowledge, came to tenth-century scholars of all faiths through the work of a Roman named Boethius (d. 524), and by his time a lot of what the Greeks had figured out had already been lost. He lived in the late 400s and early 500s CE, so while he was a Roman of high birth and influence, Italy was already under control of the Ostrogoths, and the Roman Empire did not exist in the way it had in prior centuries. Boethius was a gifted polymath with wide areas of expertise, writing on topics from math to poetry, music, and history. It is interesting to see how his work, so influential in Europe for the next thousand years, did not contain some of the advanced insights attained by Greek scholars. For instance, his translations of Euclid (c. 325 BCE–c. 265 BCE) on Geometry and Ptolemy (c. 100 CE–c. 170 CE) on Astronomy, if he ever made them, did not survive. The most advanced astronomy of the Greeks, such as Aristarchus of Samos' heliocentric model of the Solar System, was lost. Aristarchus of Samos (c. 310 BCE–c. 230 BCE) had shown that Earth and the other planets had to be circling the Sun at the center of the Solar System, but this critical fact was lost from European knowledge and not regained until Copernicus (1473–1543) in the early 1500s.

Gerbert of Aurillac also learned about politics and diplomacy in Andalusia. He was there at a time when diplomatic envoys travelled between the two regions—Christian Barcelona and Muslim Córdoba—attempting to keep the peace and maintain channels of commerce flowing between them. A basic framework of peace between the kingdoms had been negotiated by the Jewish diplomat Hasdai ibn Shaprut in the 950s. When Shaprut returned to Córdoba with a delegation from Barcelona, they carried with them gifts in the form of manuscripts for the Caliph al-Hakam. Gerbert may have participated in such a diplomatic exchange in the late 960s. Some historical accounts have Gerbert studying in Córdoba and at the university in Fez, which still exists as a center of higher learning. The evidence for these claims is not strong, but regardless, the influence of Islamic science and math on Gerbert's thinking is unmistakable.

Political alliances were fairly fluid in Andalusia in those days; Muslim and Christian leaders were often allied with one another. Once, in 988, Count Borrell wrote to the Frankish King Hugh Capet (938–996) asking for help in a territorial dispute with the Saracens. Capet offered some aid, but chastened Borrell for sometimes having closer ties to Córdoba than to France.

In late 970, Count Borrell travelled to Rome to make the case to Pope John XIII (d. 972) that his kingdom needed its own archbishop, because at the time the churches and monasteries were still controlled by the Archbishopric of Narbonne, 250 km and several weeks' travel away. Borrell took

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Abbey of Saint-Michel-de-Cuxa

the young Gerbert with him, as he had shown himself to be a brilliant student and advisor to the Count. There, Gerbert met the Pope and many others who would change his life—the most important being the Holy Roman Emperor Otto the Great (912–973), ruler of Germany and much of Italy. Otto needed a tutor for his son and heir, Otto II (955–983), who was then about sixteen, and Gerbert was given the position. While in Rome, Gerbert also met Archbishop Adalbero (d. 989) of Reims. The Cathedral at Reims in northern France was arguably the most important in France: the kings of France were traditionally crowned there, and it was the dominant center of learning in France at the time. Adalbero and Gerbert made a fast and lasting connection as countrymen and kindred spirits in reverence for teaching the trivium and the quadrivium, and later in his life Gerbert came to succeed Adalbero as Archbishop of Reims.

An important influence on Gerbert and his long life as a teacher was the mathematician Muhammad ibn Musa al-Khwarizmi (c. 780–c. 850). As much as anyone, his approach to math and science can be seen in everything Gerbert did. Al-Khwarizmi's work reveals the way that Islamic thinkers brought together different strands of Mesopotamian, Greek, Persian, and Indian thought. Just as there is a direct connection between al-Khwarizmi and Gerbert, the line continues to Copernicus, Newton, and Einstein.

Al-Khwarizmi was one of the most outstanding minds of the Islamic golden age of scholarship, from around 800 to 1250 CE. Details of his early life are not well known, but he was born into a Persian family and trained in Baghdad at the library and scholarly center known as the House of Wisdom. There he had access to the writings of classical Greek scholars as well as scholars from ancient Mesopotamia, Persia, India, and China. Scholarly pilgrims from Europe, Asia, and Africa came to study there, including Hindu, Jewish, and Christian researchers. Al-Khwarizmi eventually came to lead the institution. At the peak of the House of Wisdom's influence, it had over 400,000 volumes and documents, perhaps as many as a million. The library and the seat of the Caliphate were destroyed by a Mongol invasion in 1258, but many volumes were saved. The largest comparable library in Christian Europe at the time of Gerbert had fewer than 2,000 volumes.

Al-Khwarizmi worked in arithmetic, algebra, and geometry, and applied his methods to the material world through observation, using tools like the astrolabe and sundial. He was an astronomer, astrologist, and geographer. He systematized and elaborated on the system of Hindu-Arabic numerals from one through nine and zero, which allowed for calculations more complex than could be managed using the Roman numeral system. His most important work in mathematics was *fī ḥisāb al-jabr wa'l-muqābala*, or *The Compendious Book on Calculation by Completion and Balancing*. Notice the term "al-jabr"—algebra—in the title. The book spells out how to solve linear and quadratic equations. In Europe, al-Khwarizmi's name was Latinized to Algorithmi, the source of our term "algorithm." Al-Khwarizmi's book made its way to the libraries at Fez and Córdoba. It was translated into Latin in Andalusia in the late 900s by a monk named Lupitus, and Gerbert was able to gain access to it through him.

Gerbert de Aurillac learned how to use several other instruments in his time in Andalusia, including the astrolabe and armillary sphere. Both these devices date back to Greek times and were also independently invented in China. The simplest function of an astrolabe is to measure the height of a star or object above the horizon—its azimuth, another Arabic word. But these measurements can be combined with the location and orientation of the user and the time of the observation to record precisely where objects are relative to Earth. The positions of stars and planets can be inscribed on the surface of these objects to record the positions of celestial bodies in order to allow the user to calculate where they have been and will be, and thus predict eclipses and other astronomical phenomena. The armillary sphere works in just the same way but is sometimes shaped like a globe, or more often a series of circular rings, that can delineate the horizon, the arc fol-

lowed by the Sun and planets, and other paths of movement. Gerbert had several instruments of this nature, and the armillary sphere was probably what later detractors described as the "brazen head" that would tell the future.

What seemed to propel Gerbert's intellectual life most was the linkage of mathematics to the real world. It is certainly behind the way he taught his many students at Reims. He wanted to connect theory with observation. To look up where

BAYERISCHE STAATSBIBLIOTHEK

Otto III with Gerbert at his right elbow

BIBLIOTHÈQUE NATIONALE DE FRANCE

At the Council of Clermont in 1095, Pope Urban II rallied Europeans to attack Arabs and Turks in the lands that are now Turkey, Syria, Lebanon, and Israel. Miniature from Les passages d'outremer *(Overseas Crossings) by Sébastien Mamerot (c. 1474)*

Venus would be at a given time on an astronomical table was impressive, but putting this theoretical knowledge into practical use—to dial the figures into a sighting device and have it point precisely to Venus—was his passion. Another example involved musical instruments. Gerbert built "monochords," which were single-string devices that demonstrated the mathematical properties of sound. Divide the string's length in half and the pitch produced was an octave higher, and the string oscillated at twice the frequency as it did before. Divide it in half again and the pitch is two octaves higher and four times the frequency. The Greek philosopher Pythagoras (c. 570 BCE–c. 490 BCE) was also fascinated by the mathematical elegance of sound and the way it could be broken down in ratios to perfect fifths (3:2 ratio), thirds, and other intervals. The principles that made a string of varying lengths vibrate at different frequencies also applied to wind instruments, and another of Gerbert's projects was to construct a type of mechanical organ with pipes of different volumes.

Gerbert's hands-on approach made him a sought-after instructor. He spent twenty-four years as a teacher at Reims, and students came from France, Germany, England, Italy, and beyond to study. By one count, he taught

the future kings of France and Germany, and more than a dozen boys who went on to be abbots of monasteries, bishops, and archbishops. He taught the future Pope Gregory VI (d. 1047). His relationship with three Holy Roman emperors in succession—Otto I, II, and III (980–1002)—and his relationship with French kings—threw him headlong into the politics of Europe, which were ruthless and bloody. It was impossible to stay neutral and his allegiances and the shifting political tides saw him appointed to and removed from several important posts. For example, he was forced to flee the Archbishopric of Reims, discredited and in fear of his life. France underwent a change in kingship from the heirs of Charlemagne to the followers of Hugh Capet, whom Gerbert had backed. The family of the three Ottos was extremely powerful, but reviled by the Italians and French—bear in mind that France, Italy, Germany, and others do not refer to nations at that time, but to broad geographic and linguistic groupings of natural allies, often supporting each other and as often struggling for regional power.

In the end, Gerbert's alliances with Otto II and the French king made him a strong candidate for the papacy, and he was elected Pope by the College of Cardinals in 999, the first French pope and only the second non-Italian in 250 years. For that reason, as well as his alliances with Otto and Capet, he was loathed by most of the Italian cardinals, and his life was never easy in the Vatican. There was open rebellion against him at times and Otto III died on an expedition in 1002 to quell them. In all, however, Gerbert proved to be a capable and effective Pope, with a focus on expanding the church's reach and influence in eastern and northern Europe. He strengthened the church's position in Andalusia as well.

How could a man of Gerbert's talents and achievements come to be pilloried as a heretic and devil-worshipper in just a century or two? The most important factor in this reappraisal has to do with Europe's changing relationship with the Islamic world. Gerbert was alive at a time when Europe's relationship to the rest of the world was changing. After his death, historical events went completely counter to the way Gerbert hoped they would. Instead of integrating more fully with the Islamic world, as Christian and Jewish rulers and scholars had done in Andalusia, the church and powerful kingdoms defined themselves in opposition to the Islamic world. Shortly after Gerbert's time, the kings and popes of Europe came to stoke the fear of Muslims to build their own authority. By the late 1000s, less than a century after Gerbert's death, Christendom had launched the first of many Crusades to conquer the Middle East. This political shift was accompanied by a shift in the way writers wrote about the relations between Christians and Muslims. Gerbert's scientific legacy was tainted by his association with Andalusia and his astronomical instruments and books on mathematics were reframed as manuals for summoning demons and magical talking heads.

SCIENCE HISTORY IMAGES/ALAMY STOCK PHOTO

Miniature: an astronomer using a horologium cum fistula (clock with pipe) with sighting tube for pole star to tell the time, from an Italian fourteenth century treatise on astrology.

At the Council of Clermont in 1095, Pope Urban II (c. 1035–1099) rallied Europeans to attack Arabs and Turks in the lands that are now Turkey, Syria, Lebanon, and Israel. In Andalusia, old treaties and alliances were scrapped between Christian regions and the Muslim "tarifas," or small kingdoms, that held together most of Spain. Piece by piece Christian forces were able to conquer the Iberian Peninsula, a process that culminated in 1492 with the fall of Granada. The Inquisition was invented to enforce a degree of orthodoxy and fear of heresy that had never been part of the Catholic Church before, and with it a stunningly anti-intellectual agenda was adhered to that lasted into the Renaissance, nearly silencing scientists such as Galileo (1564–1642) and Copernicus.

While Gerbert of Aurillac's personal history was misrepresented in this process, he and many other like-minded scholars reinvigorated European scholarship with Greek and Arabic texts and new knowledge of mathematics and astronomy. These turned out to be the indispensable building blocks of Europe's own scientific revolution a few centuries later.

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