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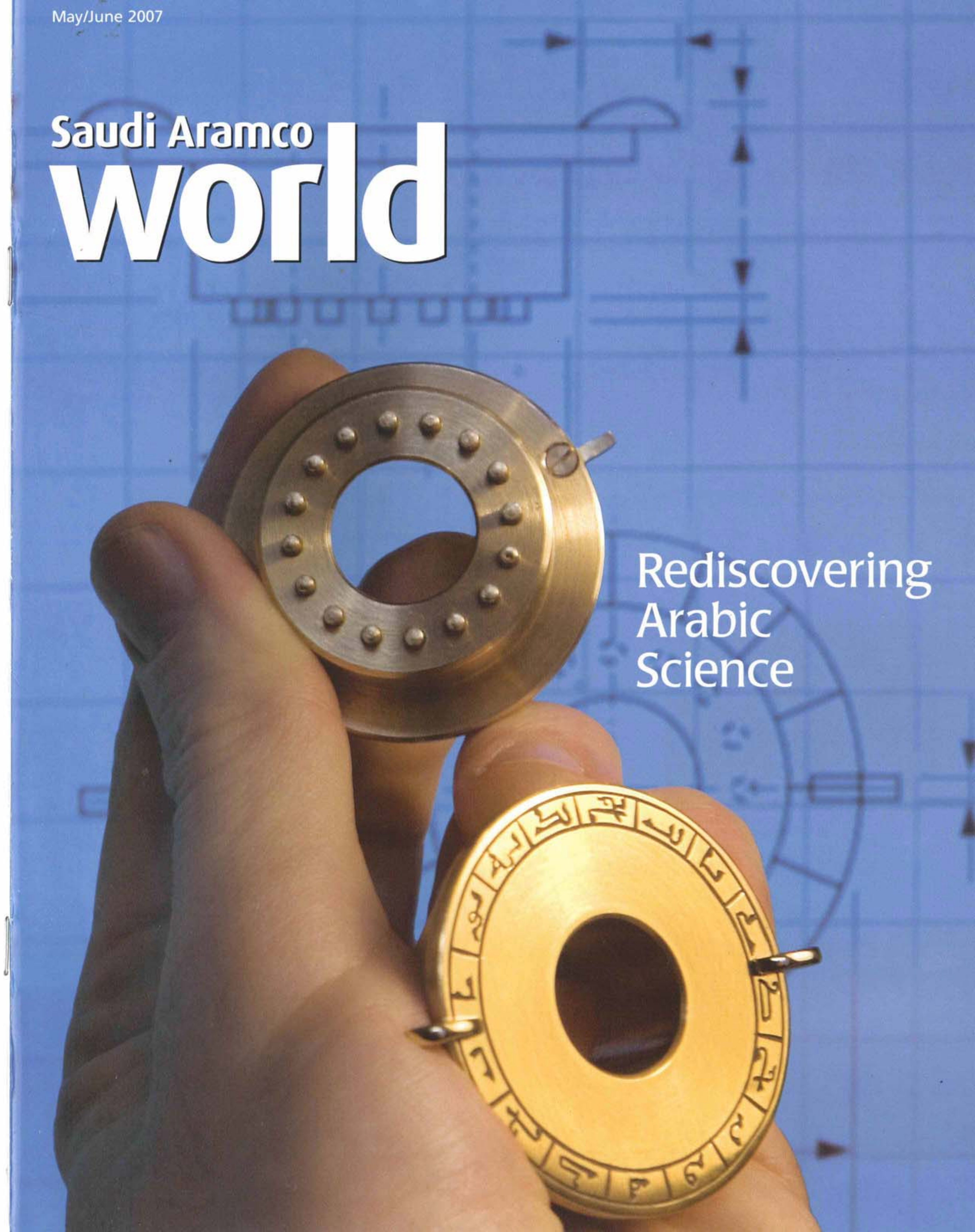

Rediscovering Arabic Science

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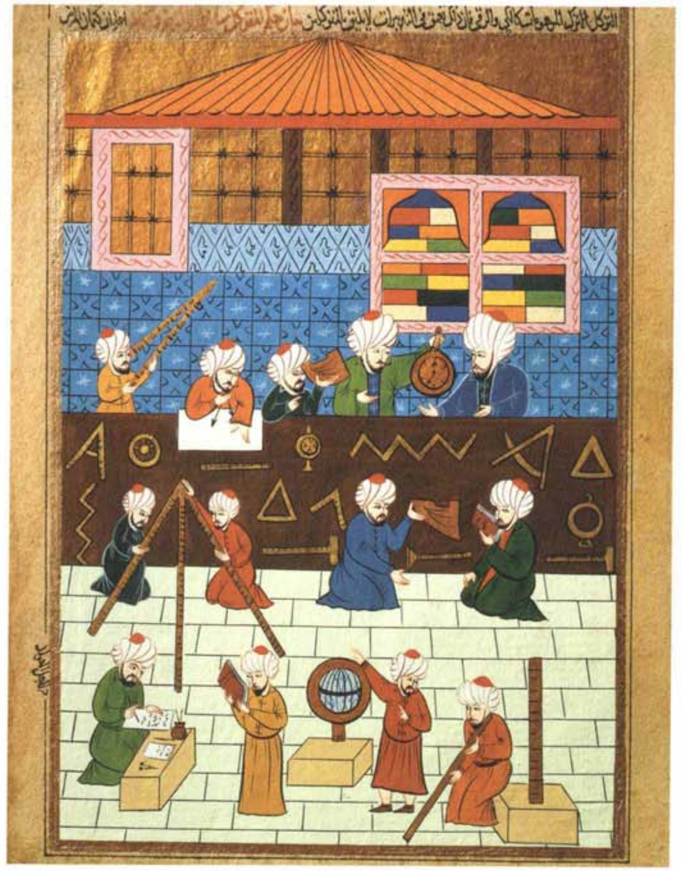

Cover:

The Institute for the History of Arab-Islamic Science in Frankfurt uses descriptions and illustrations in medieval Arabic texts along with modern computer-design tools to build facsimiles of some of the technological achievements of the Middle Ages, such as this combination lock designed by al-Jazari in the early 13th century. Besides some 800 such artifacts, the Institute's collection also includes a 25,000-volume library. Photo by Thorne Anderson.

Back Cover:

Most children growing up in Los Angeles' South Central area cannot see a doctor regularly, for there is only one local physician for approximately every 29,000 people, and most South Central families are uninsured. In this setting, UMMA's 15 staff physicians and 20 part-time volunteers offer a ray of hope. Photo by Ben Tecumseh DeSoto.

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Rediscovering Arabic Science

WRITTEN BY RICHARD COVINGTON

You have to hand it to Ahmed Djebbar: The science historian certainly knows how to draw a crowd. As we circulate among the astrolabes, maps and hydraulic models of an eye-opening Paris exhibition on medieval Arabic science, curious museum-goers gather around us.

"Did you know that the Egyptian doctor Ibn al-Nafis recognized that the lungs purify blood in the 13th century, nearly 350 years before the Europeans?" he asks, standing in front of an anatomical drawing of the human body. "Or that the Arabs treated the mentally ill with music therapy as early as the ninth century?"

Examining a case of rare manuscripts, the dapper Lille University professor launches into a mini-lecture before the rapt group. The 13th-century Persian astronomer Nasir al-Din al-Tusi, the author of one of the yellowing Arabic-language texts, upended the geocentric Greek view of the universe, Djebbar explains, by declaring Ptolemy's model

Above: The 10th-century astronomer Abu Sa'id al-Sizji held the contemporary view that the Earth was the center of the universe, but he modeled the solar system on the concept that the Earth rotated on its axis—as shown in this display at the Institute for the History of Arab–Islamic Science in Frankfurt. Left: An astronomer calculates the position of a star with an armillary sphere and a quadrant in this illustration from a 16th-century Ottoman manuscript.

LEFT: ART ARCHIVE / UNIVERSITY LIBRARY ISTANBUL / DAGLI ORTI; RIGHT: THORNE ANDERSON

of planetary motion flawed and creating his own more accurate, but still Earth-centered, version. Three centuries later, the Polish astronomer Nicholas Copernicus borrowed al-Tusi's model to make the shocking proposition that the Earth revolves around the sun.

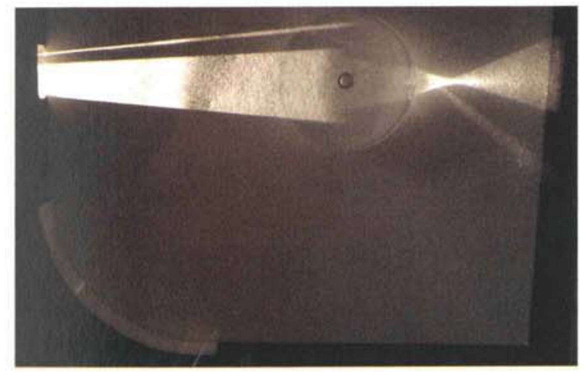
"Al-Tusi made his observations without telescopes or even glasses," says Djebbar, removing his own spectacles and waving them theatrically in the air. "Even though the Arabs possessed the knowledge to make lenses, they probably thought it was an idiotic idea. God made us like this; why hang something on our noses to see better?" he jokes, placing his glasses back on his nose with a flourish. His audience erupts into laughter as Djebbar, who was curator of "The Golden Age of Arabic Sciences"—the Paris exhibition, which ran from October 2005 through March 2006 at the Arab World Institute—tries to quiet them down.

For most westerners, and indeed for many Arabs, the spectacular achievements of Arabic-language science from the eighth through the 16th centuries come as a startling discovery, as if an unknown continent had suddenly appeared on the horizon. In mathematics, astronomy, medicine, optics, cartography, evolutionary theory, physics and chemistry, medieval Arab and Muslim scientists, scholars, doctors and mapmakers were centuries ahead of Europe. Centers for scientific research and experimentation emerged across Muslim lands—in Baghdad, Cairo, Damascus, Samarkand, Shiraz, Bukhara, Isfahan, Toledo, Córdoba, Granada and Istanbul.

Generations of science historians once rejected Islamic accomplishments.

For most Westerners, and indeed most Arabs, **the spectacular achievements of Islamic science from the eighth through the 16th centuries come as a startling discovery**, as if an unknown continent had suddenly appeared on the horizon.

One critic, the French physicist Pierre Duhem, even accused Muslims of trying to destroy classical science in his 1914–1916 historic survey *Le Système du Monde (The System of the World)*. Others asserted that the Arabic language itself was not suited for science, contends Roshdi Rashed, the dean of Islamic science in France. "Otherwise well-respected scholars like Ernest Renan and Paul Tannery excluded even the possibility of an Arabic contribution to science," says Rashed, a former fellow at the Institute for Advanced Studies in Princeton, professor emeritus at the University of Paris and editor of the three-volume *Encyclopedia of the History of Arabic Science*.



Above right: Kamal al-Din al-Farisi's 13th-century demonstration of the separation of the visible spectrum of light by double refraction, reproduced in this display at the Institute for the History of Arab–Islamic Science in Frankfurt, helped advance the science of optics. Above: The earliest known medical description of the eye, from a ninth-century work by Hunayn ibn Ishaq, is shown in this copy of a 12th-century manuscript at the Institute.

THORNE ANDERSON (2)

Although an alternative spectrum of science historians, beginning with the 19th-century European Orientalists Jean-Jacques Sédillot and Eilhard Wiedemann and including the 20th-century Harvard professor George Sarton, staunchly promoted the pivotal Arab/Muslim role in science, the general public has remained largely unaware of Arab discoveries. The 1300-year period between the Greek golden age of science (from the fifth century BC to the second century of our era) and the 15th-century Italian Renaissance was perceived as a scientific desert. If Arab scholars were acknowledged at all outside academia, they were seen merely as useful messengers, conduits who preserved the classical Greek knowledge of Euclid, Aristotle, Hippocrates, Galen, Ptolemy, Archimedes and others through Arabic texts.

True enough, much of ancient science came back to Europe via Arabic translations, which were subsequently translated into Latin and other languages. (See "Lines of Transmission," page 10.) Some key texts, like Ptolemy's *Planisphere*, Galen's commentary on Hippocrates' treatise *Airs, Waters, Places* and the final chapters of the third-century BC mathematician Apollonius' book on conic sections exist only thanks to the Arabic translations, since the original Greek manuscripts have all disappeared.

But according to astrophysicist Jean Audouze, director of the French National Center for Scientific Research in Paris, the Arabs were not simply transmitters of Greek concepts; they were creators in their own right. Like Djebbar and Rashed, Audouze is one of a small number of dedicated scholars—fewer than 150 in France, Germany and Britain, but also scattered through the US, Arab countries, Asia and Latin America—who are struggling to give Arabic science the long overdue respect it deserves.

"One of the more drastic consequences of the dismissal of the vast Islamic contribution is that you cannot understand classical science without it," argues Rashed. "If you reduce the distance between Greek science and 17th century science, you are going to say, for example, that Apollonius first conceived algebraic geometry. But he has nothing of the kind in his writings.

"Either you push Apollonius to invent ideas he did not have or you pull back 17th-century scholars closer to Greek levels of understanding. This results in very serious errors of perspective. But if you take into account Arabic science, you are better able to understand what is truly new in the 17th-century outlook and the steps that led from Greek classical science."

Arab astronomers study the heavens in this print from a commentary on Cicero's *Somnium Scipionis*, whose central character ranges through the celestial spheres that surround the Earth, and carry the planets and the stars.

In fact, the discipline is everywhere in a deepening crisis, warns George Saliba, professor of Arabic and Islamic science at Columbia University. "The most urgent need now for the study of Islamic science is to train people who can edit and publish the hundreds of scientific texts that are still lingering in world libraries with almost no one aware of their existence, let alone their contents," he says. "But despite this need, Islamic science historians are becoming an endangered species." To make his point, Saliba cites the 200 to 300 Muslim treatises on planetary theories that he's tracked down. Only two have been translated into European languages—one into Latin centuries ago and the other, in modern times, into English.

Yet the duty to promote the Arab intellectual legacy has never been greater, argues Rashed, underscoring the philosophical alliance between science, which strives for unity in the natural world, and religion, which seeks a similar balance in the realm of the spirit. "Muslim science demonstrates that there has always been a profoundly rational base to Islamic civilization," he explains.

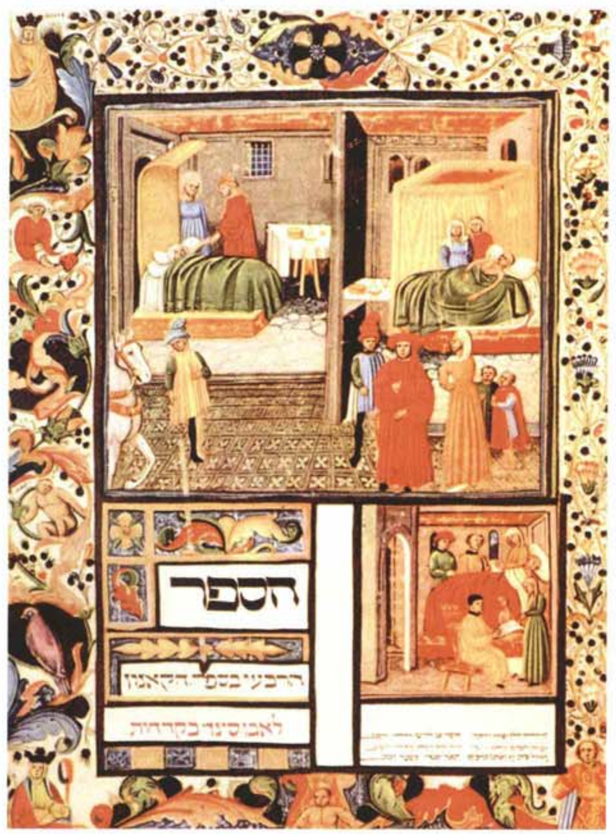
> Drawing principally from Greek texts, but also Persian and Indian sources, **medieval Islamic scientists made a staggering number of breakthroughs.**

Drawing principally from Greek texts, but also Persian and Indian sources, medieval Islamic scientists made a staggering number of breakthroughs. The brilliant ninth-century Baghdad mathematician Muhammad ibn Musa al-Khwarizmi invented algebra, initially to resolve property disputes (even though countless generations of high school students wish he hadn't bothered). He also solved linear and quadratic equations using algorithms, the basis of computer programming; the term itself is derived from his surname, testimony to al-Khwarizmi's enduring gift to mathematics.

Reversing the false Greek notion that light is emitted from the eye,

Tunisian geologist Mustafa El-Tayeb, director of science policy and sustainable development for the United Nations Education, Scientific and Cultural Organization in Paris, is another impassioned advocate for Islamic science. He believes that reclaiming a proper place for medieval Arab achievements is vital for encouraging future generations of Arab and Muslim researchers.

"When I hear reactionaries preaching to young Muslims that science is not good for Islam, I want these students to realize that it's a crucial part of their heritage and not something to be rejected, or seen as alien," says El-Tayeb. "As it is, the history of Islamic science is barely taught at all in universities across the Middle East."



The *Canon of Medicine* by Ibn Sina (known as Avicenna in the West) was first translated from Arabic into Latin in the 12th century and into Hebrew in 1279. It served as the chief guide to medical science in Europe and was used in medical schools there until the mid-17th century.

UPPER: INTERFOTO PRESSEBILDAGENTUR / ALAMY; LOWER: BIBLIOTECA UNIVERSITARIA DI BOLOGNA / NATIONAL LIBRARY OF MEDICINE

THE PRINT COLLECTOR / ALAMY

Arabic Science: **The Language**

WRITTEN BY RICHARD COVINGTON

A thousand years before English emerged as the international language of science in the latter half of the 20th century, the Arabic language unified scholars across the Muslim world, generating a lively market of ideas from Samarkand to Córdoba. "A book published in Central Asia could be read in southern Spain less than a year later," explains Roshdi Rashed, an eminent Egyptian-born historian of science, in his office near Paris. "Islamic learning was not like Greek science, which was limited principally to the eastern Mediterranean, but was spread across most of the known world."

One celebrated example is the *Kitab al-Istikmal*, a treatise on geometry by Yusuf al-Mu'taman, the 11th-century king of Sarakusta (today's Zaragosa in northern Spain). The Jewish philosopher Maimonides brought it from Córdoba to Cairo and copies were soon circulating in Baghdad. The work was eventually republished in the 13th century in Central Asia.

Among the babel of scientists and scholars who crisscrossed the polyglot Muslim empire, the common language was Arabic. "Besides Maimonides, you have the great mathematician and physicist Alhazen (Ibn al-Haitham) moving from Basra to Cairo," says Rashed, "and the astronomer Nasir al-Din al-Tusi journeying every year from Khorasan in northern Iran through Iraq and on to Aleppo to teach." Even if scholars spoke Persian or another language at home, they wrote their papers in Arabic so that their colleagues in Baghdad, Toledo and elsewhere could understand them, he adds. Omar Khayyam may have penned his quatrains in Persian, but he explicated his mathematical concepts in Arabic. Correspondence among scientists—typically carried by caravan messenger or carrier pigeon—was nearly as far-reaching in the 11th and 12th centuries as it was in the 17th, Rashed maintains.

But despite its ultimate ascendancy, scholarly Arabic had a slow start. "Before the advent of science, Arabic was the language of poetry; it soon became the language of the new religion of Islam, but paradoxically, it did not become the language of power right away," explains French science historian Ahmed Djebbar. Although the Umayyad caliph 'Abd al-Malik decreed at the beginning of the eighth century that government institutions, schools, courts and communications conduct their business in Arabic, it took another 50 to 100 years before the translation of scientific texts from Greek, Syriac, Persian and Indian languages into Arabic got under way in earnest, with some 100 translators at work over the course of the ninth and 10th centuries, according to the 10th-century bibliographer Ibn al-Nadim of Baghdad.

From Baghdad's Bayt al-Hikmah ("House of Wisdom"), the Islamic world's premier science academy for some 400 years until the city's destruction by the Mongols in 1258, came translations of Greek mathematical and scientific papers, breakthroughs in geometry and discoveries in fields from hydrology to medicine.

Baghdad's Bayt al-Hikmah ("House of Wisdom") became a vibrant center of translation. Works like Ptolemy's *Almagest* and Dioscorides' *De Materia Medica* were translated numerous times as scholars perfected Arabic terminology. The Greek word *parabola* was initially Arabicized phonetically as *barabula*, then subsequently refined to *qat za'id*, which literally means "thick section." *Diabetes* was first rendered as *diyabita* then transformed to *da as-sukkar* ("sugar sickness").

Over time, Arabic scientific terms and star names were adopted into other languages, a list that includes *alkali, alcohol, algebra, algorithm, alembic, alchemy, azimuth, elixir, nadir, zenith,* Betelgeuse, Aldebaran, Rigel and Mizar.

After some seven centuries in which Arabic dominated scientific discourse, it began to be eclipsed in the 15th century by Turkish as Ottoman rule expanded. Ghiyath al-Kashi's 1427 mathematical treatise *Risala al-Muhitiya (Treatise on the Circumference)*, in which he calculated the value of *pi* to 17 decimal places, was one of the last significant scientific texts in Arabic. By the time Taqi al-Din, the director of the Istanbul observatory, wrote his books in Arabic on light and marvelous machines in the second half of the 16th century, Latin had largely supplanted Arabic as the universal language of science. Unlike Arabic, however, which was understood by all classes and gave ordinary Muslims access to scholarly knowledge, Latin was used principally by academics and clergy, fencing science in as the preserve of an educated elite. ⊕

Related Articles:

Bayt al-Hikmah: M/J 82, M/A 87
English words derived from Arabic: M/A 07

the 11th-century physicist Alhasan ibn al-Haitham, known in the West by his Latinized first name as Alhazen, correctly asserted in Cairo that light rays travel in the opposite direction, reflecting off the surface of objects to enter the eye. Devising the first rudimentary pinhole camera, or *camera obscura*, Alhazen demonstrated that light emanates from an object in straight lines, establishing the principle of linear perspective essential to the art of Leonardo da Vinci and other Renaissance masters. (Alas, the Basra-born scientist did not invent film for his primitive camera; civilization would wait until the 19th century for the first photograph.) By putting his concepts to various tests, using the camera obscura and other tools, Alhazen also introduced the experimental method of proof, insisting that theories had to be verified in practice, a key element to modern science that was missing from the less empirical Greek tradition.

"Arab science succeeded as much in pragmatic applications as it did in theoretical concepts," Audouze maintains. "Islamic scholars distinguished themselves from their Greek predecessors, who were more inventive in ideas than in practical matters." Arab scholars also introduced the practice of peer review and citations to confirm their source material.

Although the Babylonians, Indians and Egyptians had astronomical observatories, those founded under Islamic rulers in Maragha (in present-day Iran), Samarkand and Istanbul were far more sophisticated, equipped with an impressive array of astrolabes, sundials, sextants, celestial globes and armillary spheres to track the movements of the planets and constellations.

Skilled at determining the precise location of Makkah from anywhere in the Muslim empire, Islamic astronomers were unsurpassed in their calculations and predictions. Many mosques engaged a full-time astronomer, called a *muqqawit*, to determine the hours of prayer and consult lunar calendars

Top: **The Persian polymath-physician Avicenna appeared with his Greek forebears Galen and Hippocrates in this woodcut from an early 15th-century Latin medical book.** Bottom: **Avicenna remains a hero today. His portrait decks a wall in Bukhara, Uzbekistan.**

to fix the dates for Ramadan and other religious events.

Persian astronomer Muhammad ibn Ahmad al-Biruni (973–1048), a protean intellectual figure who wrote in Persian, Arabic, Greek, Hebrew and Sanskrit, and lived in Kath (in present-day Uzbekistan), corresponded with Abu al-Wafa, another astronomer 2000 kilometers (1242 mi) west in Baghdad, to coordinate the simultaneous observation of a lunar eclipse. On May 24, 997, according to al-Biruni's book *Al-athar al-baqiyah an al-qurun al-khaliyah (Vestiges of Bygone Days*, usually shortened to *The Chronology*), they got their eclipse, measuring its duration and the moon's angle in the sky to calculate the longitude of Kath with unprecedented exactitude.

Arab astronomers and cartographers strove for—and frequently achieved—uncanny accuracy. To ascertain the distance separating degrees of longitude for a projected global map, the ninth-century Baghdad caliph al-Ma'mun dispatched 70 scientists into the Syrian desert. Using astrolabes, measuring rods and stretched lengths of cord, the teams walked until they observed a change of one degree in the elevation of the polestar, the equivalent to a degree of longitude. Reckoning the distance traveled at 56⅔ Arab miles (64.5 statute miles or 103.8 km), they computed the Earth's circumference, which is 360 degrees of longitude, as 23,220 statute miles, or around 37,380 kilometers, a respectable error only about seven percent less than the true figure of 24,800 miles (40,000 km). (However, around 200 BC the Alexandrian geographer Eratosthenes handily beat their estimate, calculating the Earth's circumference at 39,690 km.)

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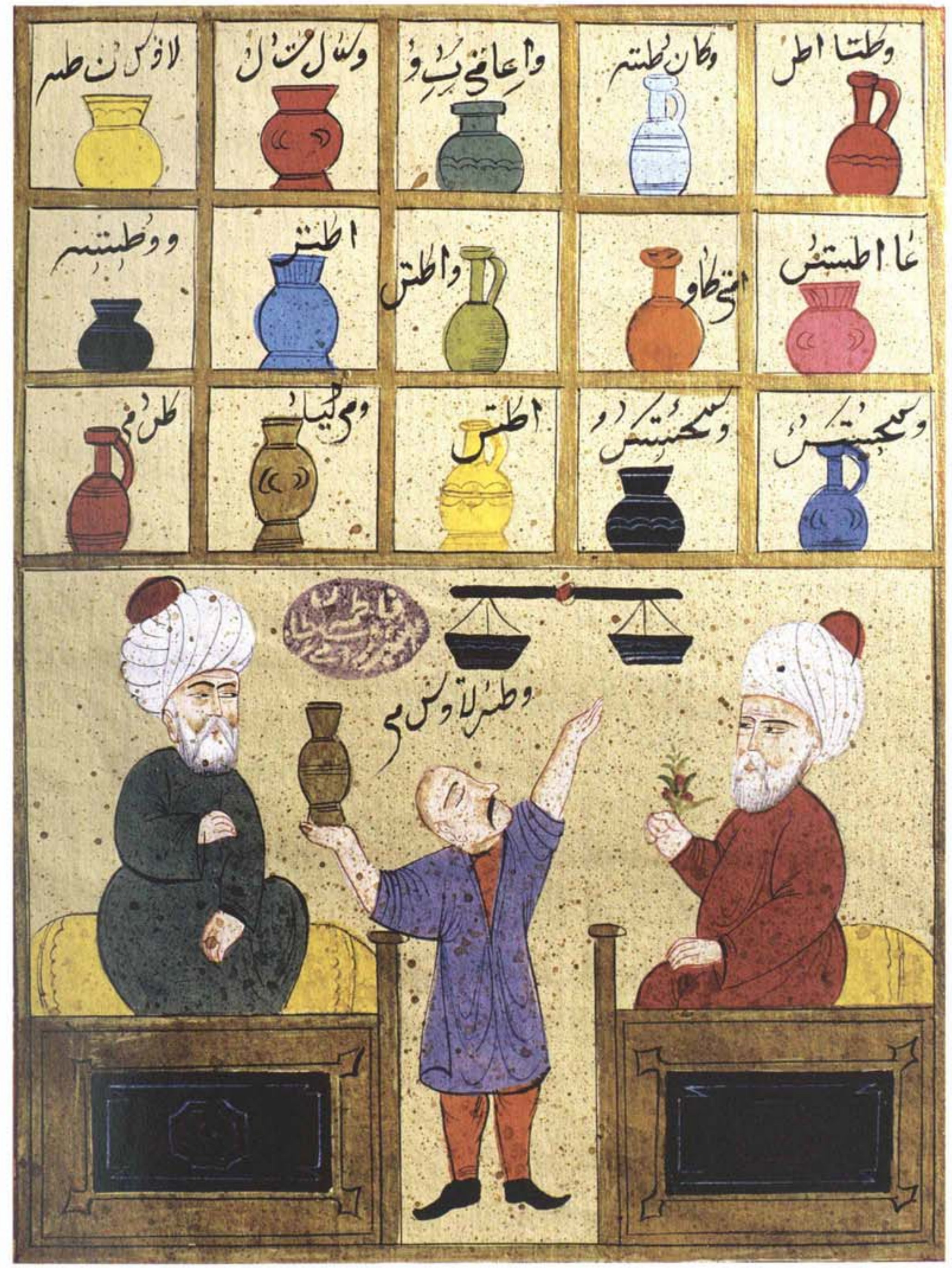
Arabic/Muslim achievements in medicine were also impressive. The ninth-century Persian doctor Muhammad ibn Zakariya al-Razi, known in Latin as Rhazes, penned the first treatise on smallpox in his *Kitab al-tajarib (Book of Experience)*, which probed some 900 cases of various maladies. Another Persian doctor, Abu Ali ibn Sina, or Avicenna (980–1037), compiled *Qanun fi 'l-tib (Canon of Medicine)*, a five-volume compendium of Greek and Islamic healing that became one of the principal textbooks in European universities centuries later.

Abu al-Qasim al-Zahrawi (Abulcasis in Latin), a 10th-century surgeon in Córdoba, composed *Al-Tasrif*, a 30-chapter medical encyclopedia describing dozens of operations, complete with graphic illustrations of surgical instruments, including scalpels, cauterizing tools, feeding tubes and cupping glasses. (A 15th-century Turkish edition added instructively terrifying depictions of doctors treating patients.) Some 300 years after al-Zahrawi, another Andalusian doctor, Ibn al-Baitar, published *Al-jami li mufradat al-adwiyya wa l-aghdhiyya (Book of Simple Medications and Alimentations)*, adding more than 400 medicines and curative plants to the 1,000 catalogued by the first-century doctor Dioscorides and other Greek botanists.

Arab scholars even theorized about evolution, arriving at conclusions that anticipated Darwin. In 1377, nearly half a millennium before the 1859 publication of *On the Origin of Species*, the Tunisian-born historiographer Ibn Khaldun, renowned as one of the founders of sociology, asserted in *Al-Muqaddimah (Prolegomena)*, "The animal kingdom was developed, its species multiplied, and in the gradual process of Creation, it ended in man … arising from the world of the monkeys."

The period from the ninth through the 16th centuries was also a golden age for hydraulic technology, with Muslim engineers devising underground canals, dams, waterwheels and water-lifting machines to modernize agriculture and provide fresh water to rapidly growing cities from Córdoba to Samarkand. Intricate water clocks, pumps and piston-driven machines were the forerunners of mechanisms that would not appear in Europe until the Italian Renaissance and later with the development of steam and internal-combustion engines in the 18th and 19th centuries.

The importance of *all* branches of learning, including science, is emphasized in the Qur'an itself, which reads, in Chapter 58, Verse 11, "God will raise up in rank those of you who have been given knowledge." The value placed on scholarship by Muslims at large is underscored by two sayings popularly linked to the Prophet Muhammad: "Search for learning even if it be in China," and "The quest for learning is a duty for every Muslim."



Arab physicians added hundreds of medicines to those recorded by the Greeks. In this Ottoman manuscript, two doctors give instructions on the preparation of prescriptions.

Although these sayings cannot be traced to authentic *hadiths* (traditions) of the Prophet, they reflect the general feeling of esteem in which the Muslim community holds learning, based on the Qur'an's emphasis on the importance of knowledge and reason, and respect for learned persons.

To Djebbar, early theological debates over the meaning of the words in the Qur'an, interpretations of hadith and etymological arguments on the Arabic language itself all nurtured the questioning spirit of rationalism necessary for scientific development. "These [religious and linguistic] critiques are the true departure point for the Arabic scientific tradition," he asserts in his 2001 book, *Une histoire de la science arabe (A History of Arabic Science)*.

Although Umayyad princes filled libraries in Damascus with Greek scientific texts from Spain, beginning in the early eighth century, and commissioned Arabic translations, the main push for scientific inquiry arose in Baghdad around the time of the city's founding in 762.

UPPER: BETTMANN / CORBIS; LOWER: CHARLES & JOSETTE LENARS / CORBIS
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Beginning with the first Abbasid caliph, al-Mansur, the victorious dynasty promoted science for ideological and political reasons. "The new rulers needed capable astronomers and geographers to measure the recently conquered empire under their control and to demonstrate to their subjects that Abbasid power was a force for good," Djebbar explains. As rural populations migrated to the cities, creating a highly diverse, socially volatile mix of peoples, the demand for competent doctors, engineers and scientists exploded. Baghdad had a population of more than 800,000 inhabitants by the 10th century, and was, after Constantinople, the largest city on Earth.

At the end of the eighth century, Harun al-Rashid, the grandson of al-Mansur and the caliph whose court inspired *The Thousand and One Nights*, erected Baghdad's first paper mill, the second in the empire. (The first mill had been constructed in Samarkand by Chinese engineers captured in the Battle of Talas in Central Asia around 750, according to Djebbar. The Chinese, who had been making paper since at least the second century BC, had kept the process a jealously guarded secret.) Shortly after the Baghdad plant opened, paper mills cropped up in virtually all the major Muslim cities. By the end of the 12th century, the Moroccan capital Fez sustained some 400 paper-making workshops.

The introduction of paper into the Middle East was a key technological breakthrough and a critical innovation for the spread of science. Paper gradually supplanted parchment and papyrus, making publication of manuscripts far cheaper and providing access to ideas for a much broader range of the educated public. Feather-light but sturdy paper was developed for use in correspondence by carrier pigeon. Since al-Biruni's *Chronology* mentions an exchange of letters with Abu al-Wafa to measure an eclipse, Djebbar suggests that the two astronomers used carrier pigeon "air mail" to speed up their 2000-kilometer correspondence between Kath and Baghdad.

Around the same time that Harun al-Rashid ushered in the paper mill, he also founded Baghdad's first hospital and a separate scientific academy known as Bayt al-Hikmah ("House of Wisdom"). Initially little more than the caliph's private library, the House of Wisdom became a full-blown research and translation center and astronomical observatory under al-Rashid's son, Caliph al-Ma'mun, who ruled from 813 to 833. It was here that the versatile al-Khwarizmi developed algebra and, turning his hand to cartography, drafted an elaborate map tracing the meanders of the Nile River.

Animal husbandry, particularly the care of horses, was a concern throughout the medieval Muslim world. This description of an operation is from a 13th-century Seljuk manuscript.

ART ARCHIVE / TOPKAPI MUSEUM / DAGLI ORTI

According to Ibn al-Nadim, a local 10th-century bibliographer, al-Ma'mun had a prophetic dream of the white-bearded Aristotle seated on a throne in which the Greek philosopher advised the caliph on the path to wisdom through reason, law and faith. Al-Ma'mun took this vision as a sign to amass knowledge and shortly afterward sent a cohort of academics to Byzantium to bring back reams of scientific and philosophical texts to be translated into Arabic. Gradually, scholars acquired manuscripts from state archives and private collections in Alexandria, Damascus, Antioch, Harran and other cities. Although most of the books were in the original Greek, many volumes had already been translated between the fifth and seventh centuries into Syriac, the western Aramaic tongue used in ancient Syria. This massively ambitious initiative to translate Greek, Syriac, Persian and Indian treatises into Arabic lasted more than 200 years, from the middle of the 700's until the end of the 10th century, according to Djebbar. (See "The Language," page 5.)

Al-Ma'mun's patronage set an example, prompting princes, merchants, doctors and well-to-do scholars to finance research with charitable endowments, known as *awqaf* (*waqf* in the singular). "Scientists were always close to the courts; there was no such thing as independent science," explains Rashed. "One had to eat and for that the scholars needed a patron, either the caliph, a wealthy merchant or a nobleman."

The support of powerful benefactors became a vital element for the development of science across the Muslim empire. In Córdoba, the 10th-century caliph al-Hakam II sponsored extensive scholarly missions to scour manuscript collections in the eastern capitals to stock a library that soon rivaled the best in the world. In the early 11th century, the Fatimid ruler al-Hakim invited the renowned mathematician and physicist Alhazen to teach in his court, greeting him in person at the gates of Cairo, an extraordinary honor that gave a tremendous boost to the prestige of science in Egypt. That honeymoon ended abruptly, however, when Alhazen failed to realize the caliph's scheme to regulate Nile flooding. Feigning madness to avoid execution, the scholar was placed under house arrest, taking advantage of the solitude to churn out a flood of treatises, biding his time until al-Hakim's death in 1021.

Generally, scientists worked without religious constraints, Djebbar maintains, with Nestorian Christians, Jews and Muslims collaborating in relative harmony. The sort of persecution that inflamed the Spanish Inquisition in the 15th century and later fired the 1633 heresy trial of Galileo in Rome did not occur in Islamic countries at the time, he says.

"It was not because Muslims were nicer people than Christians," the professor explains. "It was a matter of timing. In Christian countries, there was a scientific renaissance at a period when religion had already locked the doors of experimentation and speculation. In Arab countries, science arose shortly after Islam was established, creating its own secular space without reference to religion."

Top: The 10th-century Andalusian surgeon Abu al-Qasim Khalaf ibn al-Abbas al-Zahrawi (known as Abulcasis in the West) wrote many medical books, including *The Properties of Various Products*. This page discusses the use and preparation of absinthe. Bottom: Two types of thyme are depicted on these pages of *De Materia Medica*, a guide to remedies by the Greek physician Dioscorides that was translated into Arabic in Baghdad in 1240.

UPPER: BIBLIOTHÈQUE NATIONALE / ARCHIVES CHARMET / BRIDGEMAN ART LIBRARY; LOWER: ART ARCHIVE / BODLEIAN LIBRARY

There were, however, isolated instances of repression. Shortly after al-Hakam II's death in Córdoba in 976, the prime minister Abu Amir al-Kahtani, who assumed power as regent for the underage prince Hisham, burned many of the manuscripts the caliph had acquired at such great cost, claiming that the teachings of the Greeks, particularly in astronomy and philosophy, contradicted the Qur'an. Only works of medicine and arithmetic were spared. Some 150 years later, in the 12th century, the Baghdad theologian and mystic Muhammad al-Ghazali branded theoretical mathematics and physics as dangerous, claiming that they bred a rationalistic philosophy that led to atheism, according to Djebbar.

Astrology also provoked a heated polemical debate that lasted for centuries. "Critics argued that astrology lied to people by claiming to predict the future when only God can see the future," says Djebbar, "but no Muslim astrologer—and there were many at the various courts—was ever put to death because of his predictions."

Although the first astronomical tables for calculating the positions of stars and planets arrived in Baghdad from Persia and India in the eighth century, the chief reference for Islamic astronomy was Ptolemy's *Almagest*, or *The Great Book*, initially translated into Arabic by al-Hajjaj around 828. Contrary to a common misperception, the second-century scholar from Alexandria did not believe the Earth was flat. Like his Arab successors, however, he was convinced that the sun, moon and planets revolved in celestial spheres around the Earth. In an attempt to match this geocentric theory with the actual movement of heavenly bodies, Ptolemy posited an eccentric model that depended on off-center orbits that were "physically impossible," according to Saliba of Columbia University. Struggling to reconcile the Greek universe with their own observations led a number of Islamic astronomers to challenge Ptolemy's faulty concepts of celestial motion.

The Syrian astronomer Muhammad ibn Jabir al-Battani, who worked in Raqqa from the late 10th century through the early 11th century, amended Ptolemy's figures for the inclination of the *(continued on page 12)*

Arabic Science: **Lines of Transmission**

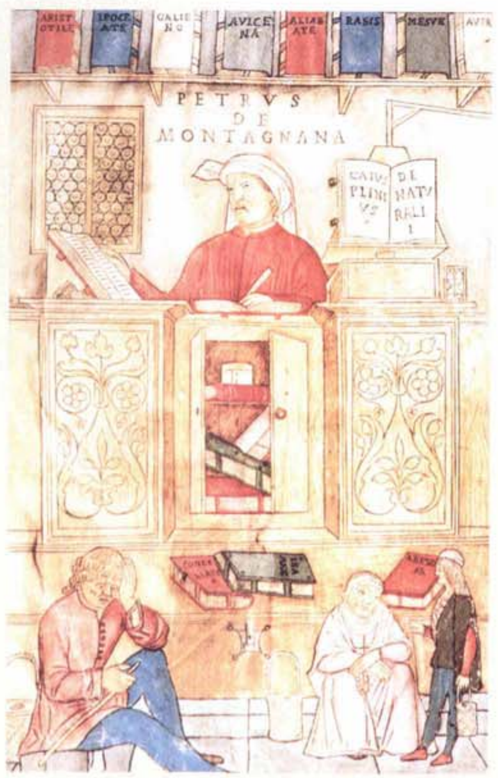
WRITTEN BY RICHARD COVINGTON

Long before Dan Brown's *Da Vinci Code* popularized the Fibonacci sequence as an early clue to his murder mystery, the 13th-century Italian mathematician who gave his name to that number series was learning the principles of advanced arithmetic from Arab teachers in Bejaia, in present-day Algeria. In the Fibonacci sequence, every number after 0 and 1 is the sum of the previous two numbers, so that the sequence runs: 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987, 1597, 2584, 4181, 6765, 10,946 and so on. The series appears in nature in many forms, including the spiral arrangements of sunflower seeds, pineapple fruitlets and pinecone scales; it appears in geometry, where, starting with the number 5, every *other* Fibonacci number is the length of the hypotenuse of a Pythagorean right triangle with integral sides; it recurs in mathematics, where the ratio between successive Fibonacci numbers approaches the classical "golden ratio" of 1:1.618033....

Like the Danish astronomer Copernicus and the Spanish physician Michael Servetus in the 16th century, Fibonacci, who was one of the founders of western mathematics, constructed a substantial portion of his pioneering scientific research on the foundations laid by his Arabic-speaking predecessors. Using Latin translations of Muhammad ibn Musa al-Khwarizmi's treatises on algebra and algorithms, Fibonacci, also known as Leonard of Pisa, wrote the *Liber abaci*, the first widely available book on Arabic numerals and arithmetical problems, expanding Indian-based concepts that had arrived in Spain starting in the 10th century.

On an expedition to Catalonia around 967 in search of unknown manuscripts, Gerbert, a Benedictine monk from Aurillac in Provence who later became Pope Sylvester II, came across Latin texts explaining Arabic numerals. He later taught about them, in Rheims and Rome, using a rudimentary abacus. From these modest beginnings, ancient Greek knowledge preserved in Arabic texts, as well as original Muslim science, was translated principally into Latin, Hebrew and Castilian Spanish to blossom gradually across Europe. In the courts of Toledo, Palermo and London, and the universities of Salerno, Padua, Paris and Oxford, a network of intellectual cross-pollination arose that spanned more than half a millennium, ushering in a European scientific renaissance.

Translators such as Gerard of Cremona from Italy, Adelard of Bath from England, Constantine the African, who brought an entire library of Muslim medicine to Salerno, and Michael Scot, a Scotsman who studied in Spain and Sicily, crisscrossed Europe. These itinerant scholars disseminated critical Arab revisions of Greek learning and popularized the revolutionary innovations made by generations of Islamic astronomers, physicians, mathematicians and physicists. Roger Bacon, the 13th-century proponent of the experimental method, astronomers Tycho Brahe in the 16th century and Galileo in the 17th, English physician William Harvey, who formulated his theory of blood circulation on Arab models in the 17th century, and many others owe a direct debt to Muslim knowledge brought to the West in this period.



This woodcut from a book about the nervous system, published in Venice in 1495, shows shelved reference volumes by Muslim physicians Avicenna, Rhazes and Ibn Rushd, alongside works by Aristotle and Hippocrates.

Occasionally, there was a distinctly personal link between East and West. Journeying to Aleppo and elsewhere around the Middle East, the 17th-century Dutch Orientalist Jacobus Golius, who spoke and read Arabic, brought back the tracts of Alhazen. Since his son was secretary to Descartes in the Dutch city of Leiden, Golius excitedly showed his acquisitions to the exiled French mathematician, who incorporated the Muslim physicist's findings on optics and geometry into his own writings, according to French science historian Roshdi Rashed.

The transmission of Islamic science to Europe was not a fixed event like the delivery of a package whose contents launched the Renaissance. It was an ongoing, fluid exchange over time, a transfer that traveled in both directions, although it flowed mostly from East to West. Once Christian armies began to retake Spain in the 11th century and Crusaders returned from the Middle East over the course of the 12th and 13th centuries, western scholars began a dogged search for Arabic texts. Some key Arab and Persian documents, such as Alhazen's *Kitab al-Manazir (Book on Optics)* and al-Khwarizmi's *Book on Indian Calculation*, lost in their Arabic editions, have survived thanks only to Latin translations.

"The translators were very important, but there was also a great deal of direct contact among the scientists themselves," points out Rashed. "This explains why you find the same information in Arabic and Latin texts even though they are not exact translations; there was also verbal transmission of the knowledge."

The Castilian city of Toledo, which was reconquered by King Alfonso VI in 1085 after nearly four centuries of Arab rule, became a magnet for scholars intent on harvesting Arab and Greek science. According to science historian Ahmed Djebbar of the University of Lille, more than 100 major scientific and philosophical essays were translated in Toledo from Arabic into Latin and Hebrew between 1116 and 1187. In a typical example illustrating the cosmopolitan nature of this mountaintop city, the English philosopher Daniel of Morley recounts meeting the Italian linguist Gerard of Cremona near the banks of the Tagus River. The two foreigners were awestruck by the vestiges of several monumental water clocks built by Ibrahim ibn Yahya al-Zarqali (Azarchel in Latin) shortly before the city fell to Alfonso.

By far the most prolific translator of the era, Gerard had left Italy chiefly in quest of Ptolemy's *Almagest*, which existed only in Arabic and Syriac, a pre-Islamic language of ancient Syria. Uncovering an Arabic transcription in Toledo, he stayed there 30 years, making Latin translations of Ptolemy, Ibn Sina's *Canon*, astronomical coordinates by al-Zarqali that became known as the "Toledan tables," and al-Zahrawi's manual on surgery, featuring a tonsillectomy technique as gruesome as it was efficacious.

Around the same time, Adelard of Bath, who had spent seven years traveling as far as Antioch seeking learning based on "reason rather than authority," as he wrote in *Quaestiones Naturales*, returned to the court of English king Henry I. There he introduced Muslim research on trigonometry, botany, falconry and other subjects. Soaking up Muslim mathematics and astronomy in Córdoba and Toledo, his compatriot Daniel of Morley later lectured his Oxford students that they should "not despise the simple and clear opinions of the Arabs, but should note that Latin philosophers make heavy weather of these subjects quite unnecessarily." Although Daniel of Morley's books from Spain were destroyed in English religious wars, Oxford's Bodleian Library later built up one of the most important collections of medieval Arabic manuscripts and 12th- and 13th-century Latin texts translated from Arabic sources.

The Holy Roman Emperor Frederick II, pictured in his court in Palermo, Sicily, continued the fruitful contacts with Muslim scholars initiated by his father, Roger II, even during time of war. He furthered learning by financing translations of Arabic works into Latin.

Landing in southern Italy around 1060 from Qayrawan, in today's Tunisia, Constantine the African became a Benedictine monk at the abbey of Montecassino, 130 kilometers (80 miles) south of Rome. He transcribed numerous Arabic books, including Hunayn ibn Ishaq's versions of discourses by Galen and Aristotle, Ibn Ishaq's manual on ophthalmology and the physicians' encyclopedia of Ali ibn Abbas al-Majusi. Rapidly adopted by doctors at Salerno's medical school, Constantine's translations eventually filtered into France, England and Germany.

Even the Crusades failed to slow the pace of intellectual discourse—quite the contrary, argues Roshdi Rashed. "The Crusaders brought back a great deal of science, medicine, foods and so forth from the Middle East," he explains. In the first half of the 13th century, in fact, the Arabic-speaking Holy Roman Emperor Frederick II maintained a thriving correspondence with Muslim philosophers and scientists from his court in Palermo, Sicily, and even during his occupation of Jerusalem. "When you consider the two sides were in the middle of fighting one another, this is fairly astonishing," marvels Rashed.

Frederick enthusiastically encouraged Muslim scientists, an enlightened policy of Arab–Christian cooperation begun by his father, Roger II, who had sponsored the geographer Muhammad al-Idrisi. (See "The Third Dimension," page 17.) In addition, Frederick financed translations of Arabic works, enlisting the services of Michael Scot, the astronomer-alchemist-wizard who later earned a place in Dante's *Inferno*. Scot had achieved renown in Toledo for transcribing Nur al-Din ibn Ishaq al-Bitruji's astronomical treatises on planetary motion and Averroes' commentaries on Aristotle into Latin, according to French science historian Danielle Jacquart. Both texts represented heretical challenges to Catholic doctrine, and hiring such a subversive character no doubt contributed to the emperor's ongoing problems with the church, which ultimately excommunicated Frederick II not once, but twice.

Around 1277, Toledo again became the focus of Muslim science, as King Alfonso X commissioned the first renditions of Arabic texts into Castilian Spanish instead of Latin. Apart from sponsoring the *Libros del saber de astronomía (The Books of Astronomical Knowledge)*, which incorporated Thabit ibn Qurra's revision of the *Almagest* and translations of Abd al-Rahman al-Sufi's *Suwar al-kawakib al-thabit (Treatise on the Fixed Stars)*, Muhammad ibn Ahmad al-Biruni's text on the spherical astrolabe and other Muslim texts, the king also promoted research into astrology, magic and philosophy.

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Earth's axis and was later praised by Copernicus as a source for his own heliocentric theory of the solar system. Around the same time, al-Biruni, who had been captured by Sultan Mahmud and hauled away to his court in Ghazni, in present-day Afghanistan, observed that the sun's apogee, its highest point in the heavens, was mobile, not fixed, as Ptolemy had maintained. In his comprehensive encyclopedia of astronomy, *Kitab al-qanun al-Mas'udi*, or the *Canon Mas'udicus*, dedicated in 1031 to Mahmud's son and successor, Mas'ud, al-Biruni also observed that the planets revolved in apparent elliptical orbits, instead of the circular orbits of the Greeks, although he failed to explain how they functioned. It was not until the 13th century that al-Tusi conceived a plausible model for elliptical orbits.

While parts of the *Almagest* underwent extensive revision by Arab and Persian scholars, much of this fundamental text was adopted intact. Commissioned by the Buwayid sultan Adud al-Dawla in Isfahan, the 10th-century astronomer Abd al-Rahman al-Sufi created a magnificently illustrated catalogue of the 1017 stars in 48 constellations enumerated by Ptolemy. It was a measure of the great value that medieval Muslim society placed on astronomy that this work was the first Islamic manuscript to contain figurative drawings. Al-Sufi's elegant sketches in his *Suwar al-kawakib al-thabit (Treatise on the Fixed Stars)* are filled with whimsical lions, fanciful serpents and mythological characters representing constellations and zodiacal signs. Tracing the outline of Perseus (also called Farsawus, or Hamil Ra's al-Ghul in Arabic) in red-painted stars, one dramatic scene depicts nearly identical facing images of the Greek hero, with Oriental features and flowing black hair, each brandishing a sword aloft and holding the head of a grimacing Medusa.

While some astronomers devoted themselves to illustrating or improving Ptolemy's science, others ventured forth on new tacks, designing more exact calendars, measuring eclipses and refining astronomical tables. In Cairo, the 10th-century scholar Ibn Yunus perfected tables used to calculate planetary motion to a number-crunching nine figures after the decimal point.

Nasir al-Din al-Tusi is pictured at his writing desk at the high-tech observatory in Maragha, Persia, which opened in 1259. He persuaded the Mongol conqueror Hulaga Khan to build the facility.

Three centuries later in Baghdad, the Persian polymath Zakariya al-Qazwini, a doctor, jurist, geographer and amateur astronomer, issued the first cosmography in the Muslim realm. This "layman's guide to the universe" covered everything celestial—solar cycles, weather forecasting and ruminations on the comportment of angels—and terrestrial, with fanciful illustrations depicting animal, vegetal and mineral kingdoms. Some editions of his 1270 *Kitab aja'ib al-makhluqat wa ghara'ib al-mawjudat (Book of Marvelous Creatures and Rare Things)* contain movable paper levers with the sun at one end and the moon at the other, pivoting on the Earth in the center to demonstrate how the Earth casts a shadow on the moon during a lunar eclipse—"the first interactive book," writes Parisian historian Danielle Jacquart.

One of the most forward-thinking scientific geniuses of the age was the astronomer-mathematician-theologian-physician al-Tusi. He was a Benjamin Franklin figure who persuaded the 13th-century Mongol conqueror Hulagu Khan to finance a boldly experimental observatory in the northwest Persian city of Maragha. Staffed by the most experienced astronomers in the empire, the new observatory set about educating a rising generation of stargazers. It was here that the scholar from Khorasan, who wrote more than 100 works of science, philosophy and poetry, contrived an ingenious model of heavenly motion that came tantalizingly close to explaining away the inconsistencies in Ptolemy's theories.

"Al-Tusi's couple" consists of one large circle representing the orbit of the moon and, inside it, a smaller circle, half the radius of the larger circle, that represents the orbit of a planet. Both circles, the "couple," revolve in tandem around the Earth. As the couple orbits the Earth, the moon rotates in the same direction on its own orbit and the planet spins twice as fast on its inside orbit in the opposite direction. Using this model, both the moon and the planet appear to revolve around the Earth in elliptical orbits with oscillating centers. In this mind-bending way, al-Tusi tried to reconcile the irregular movements of the sun, moon and planets, yet preserve Ptolemy's geocentric circular orbits.

Although Maragha, with its library and copper foundry for manufacturing astronomical tools, constituted one of the first astronomy schools in Islamic civilization, the observatory at Samarkand, inaugurated a century and a half later in 1420 by the ruler Ulugh Beg, the grandson of Timur (Tamerlane), was positively palatial. With its three-story tower 48 meters (156') in diameter, encircled by dozens of lofty arched niches decorated with blue, gold and green faience tiles, the observatory prided itself on its giant sextant—two stone circles dug 20 meters (66') into the ground that were used to gauge the height of the sun and the stars.

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Here, more was definitely more, and size mattered enormously. "[The astronomers] considered that the instruments of grand dimension were the best adapted [for their work] for the simple reason that they allowed them to obtain more precise measurements," writes Saliba in the catalog for the Arab science exhibition at the Arab World Institute. The celebrated Persian scholar Ghiyath al-Kashi (1380–1429), reputed for calculating the value of *pi* to 17 decimal points, was so impressed by their scale that he penned a letter to his father describing the techniques and materials employed to produce bigger—and presumably more exact—astronomical equipment.

After Maragha and Samarkand, another major observatory was built near the present-day site of Taksim Square in Istanbul around 1576, supplanting an earlier installation in the Galata Tower financed by Süleyman the Magnificent in 1557. Coming from Cairo, Taqi al-Din persuaded Sultan Murad III to found the best-equipped facility in the Muslim world. Some of the observatory's exceptional instruments are depicted in a vivid painting from the manuscript *Sama'ilnama* in the library of Istanbul University. Here, 16 astronomers sporting flamboyant white turbans engage in animated discussion as they demonstrate astronomical clocks, updated globes and newfangled compasses (one shaped like a stick tripod as big as a man) to enhance star readings.

Unfortunately, Taqi al-Din's success goaded jealous rivals to convince the sultan that the observatory was intended for un-Islamic astrology, not astronomy, according to Turkish-born Fuat Sezgin, director of the Institute for the History of Arabic–Islamic Sciences at the Goethe University in Frankfurt. Other scholars maintain that Taqi al-Din incurred the sultan's wrath when the man of science tried to play fortuneteller, interpreting a comet's passage as an omen of Ottoman victory over the Persians. (The Turks won the battle, but suffered a devastating plague and other setbacks that were blamed on the comet.) In any event, Murad ordered the magnificent edifice destroyed in 1580, dealing a significant blow to Islamic astronomy and helping to usher in a period of stagnation across all the sciences, says Sezgin. (See "The Third Dimension," page 17.)

Like astronomy, which evolved from the practical necessities of finding the directions and hours for prayers, Islamic mathematics was very much a hands-on affair at the beginning, a product of the marketplace and of the need for pragmatic legal precedents. Both algebra and the use of zero had the same end in mind—streamlining computations for business deals. Al-Khwarizmi had a hand in the development of both.

In his *Kitab al-jabr (Book of Algebra)*—the word comes from the Arabic word *jabara*, "to restore"—the Baghdad mathematician spells out his no-nonsense intent: "It's a summary encompassing the finest and most noble operations for calculations which men may require for inheritances and donations, for shares and judgments, for commerce and all sorts of transactions that they have among them such as surveying tracts of land, digging canals and other aspects and techniques."

In another treatise, the *Book on Indian Calculation*, which was lost in the Arabic original and only survived due to its Latin translation, al-Khwarizmi introduces the nine integers borrowed from the Indian system (1 through 9) and explains how zeroes are used to create multiples of ten, a hundred, a thousand and so on. Unlike archaic numerical systems, which were based on multiples of five, 12 or even 60, or cumbersome Roman numerals, the Indian–Arabic decimal system made arithmetic vastly simpler and more rapid.

Using the geometry of Euclid and Apollonius as starting points, Muslim mathematicians went much farther than their Greek predecessors. While al-Biruni promulgated the first book on trigonometry in the 10th century, it was not until the 13th century that the Maragha astronomer al-Tusi developed trigonometry into a separate discipline.

After absorbing Apollonius' book on conic sections such as circles, parabolas, ellipses and hyperbolas, and deliberating over what was contained in the lost eighth chapter, Alhazen, the inventor of the camera obscura, proposed his own version of the book's ending, adding solutions for computing the volume of a three-dimensional parabolic shape.

This translation of Euclid's *Elements of Geometry* is by the Persian scholar Nasir al-Din al-Tusi. The work is among the earliest Greek treatises on mathematics.

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In 10th-century Baghdad, the mathematician-astronomer Abu Sahl al-Quhi formulated a life-saving use of trigonometry by employing it to determine the height and position of lighthouses and to gauge distances of ships at sea from hidden shoals. The resourceful scholar also invented the so-called "perfect compass," a hand-held mechanical tool with an adjustable arm pivoting around a fixed arm, to trace ellipses and other conic sections.

Enlarging on Indian notions of the sine (the ratio of the length of the side of a right triangle opposite an acute angle to the length of the hypotenuse), the ninth-century mathematician Habash al-Hasin developed the concept of tangents (straight lines and planes touching arcs, circles and conic sections) to facilitate geometrical calculations.

When the multi-talented 11th-century Persian poet Omar Khayyam was not rhapsodizing in *The Rubaiyat* and other verse, he kept busy revising solar calendars for the Seljuk sultan Jalal al-Din and drafting geometrical proofs for cubic equations by intersecting parabolas with circles. The mathematical bard also circulated a visionary critique of Euclid's theories on parallel lines that prefigured non-Euclidean geometry, to come some 800 years later.

In several other areas, Arab mathematicians were centuries ahead of European theorists. The 13th-century scholar Ibn Munim from Marrakech used Khayyam's earlier studies to plot a triangular numerical grid that allowed him to figure permutations and combinations. This exercise yields, for example, the maximum number of words that can be created with the 28 letters of the Arabic alphabet. Four hundred years later, the 17th-century French mathematician Blaise Pascal reinvented Ibn Munim's numerical grid.

The famous last theorem by Pascal's colleague, Pierre de Fermat, offers another example of Muslim scholars presaging European discoveries. Some 600 years before Fermat posited his mathematical riddle—that there are no non-zero integers *x*, *y* and *z* such that $xn + yn = zn$ where *n* is an integer greater than 2—Muslim scientists Alhazen, al-Sizji, al-Khazin and others were grappling with a similar conundrum. Fermat's enigma would remain unsolved until 1994, when British mathematician Andrew Wiles at last provided a definitive proof.

While Islamic mathematicians outstripped their Greek and Indian predecessors, Muslim doctors used Hippocrates and Galen as springboards for their own expanded findings about medicine and anatomy. In his seminal *Canon*, Ibn Sina expanded on Hippocrates' influential fifth-century BC work, *Airs, Waters, Places,* by enumerating the effects that clean air and water and salubrious mountain and coastal environments have on health. Some Arab critiques of Greek physicians were pointedly specific. Writing about a famine in Egypt around 1200, Abd al-Latif al-Baghdadi recounts his observations of the skeletons of starvation victims, noting that the lower jaw consisted of a single bone, instead of two articulated bones, as Galen had wrongly concluded. Neither Galen nor al-Baghdadi was able to dissect human bodies, due to religious taboos that lasted until the 17th century.

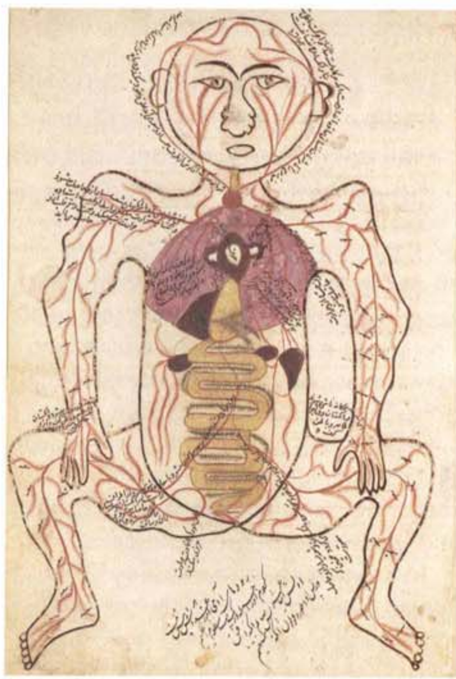
Tenth-century astronomer Abd al-Rahman al-Sufi's *Treatise on the Fixed Stars* included both pictures and written descriptions of star patterns, including the Celestial Twins of the constellation Gemini.

Even before the consolidation of the Islamic empire, the Arabs sought to raise the abysmal standards of public health, with the first Muslim hospital opening in Damascus in 706. "One of the great successes of Arabic medicine was the organization of hospitals at a level that far surpassed Greek, Roman or Persian models," says Djebbar.

Beginning in the late eighth century when Caliph Harun al-Rashid established a Baghdad hospital, doctors made daily rounds with their students, setting a precedent used in medical schools ever since. Typically, there was one courtyard wing for physically ill patients, another for those with moderate mental health problems and a third for those suffering from more severe psychological disorders. "In addition to music therapy, the courtyards all had fountains, trees and warbling birds so that the sounds of nature were part of the healing process," notes the Lille professor.

A handful of institutions boasted incredibly luxurious circumstances. According to Ahmed Issa Bey in his 1928 book *The History of Hospitals in Islam*, the 12th-century Almohad ruler Abu Yusuf Ya'qub al-Mansur provided the fortunate patients of his Marrakech facility with running water in every room, wool blankets, silk sheets, free medicines and 30 dinars a day for food and other necessities. When indigent patients got well enough to leave, they received a small sum of money to ease their reentry into working society.

A few of these medieval hospital buildings still exist intact, even though they now serve different purposes. Aleppo's 14th-century Argun Maristan is a dramatic backdrop for folk dance, and a 12th-century stone hospital in Damascus houses the National Museum of Arabic Medicine and Science. Cairo's Qalawun hospital, which treated some 4000 patients a day when it was constructed in the 13th century and accommodated lecture halls, a mosque and doctors' residences, is currently one of the top ophthalmology clinics in Egypt.



Mansur ibn Ilyas's 14th-century work on anatomy contained illustrated chapters on five systems of the body: bones, nerves, muscles, veins and arteries. This page depicts the arteries, with the internal organs shown in watercolors.

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Although physicians had to be certified, scores of uncertified barbers and itinerant surgeons practiced bloodletting, tooth extraction and more dangerous operations with few anesthetics or antiseptics. Surgery was so chancy in the 10th century that even the adventurous doctor Rhazes refused to allow ophthalmologists to remove his cataracts. But by the 14th century, the situation had improved dramatically. Persian surgeon Mansur ibn Ilyas produced sophisticated anatomical drawings tracing nerves, veins, arteries, muscles and complex organs like the heart and brain that aided him immensely in conducting effective operations.

Al-Zahrawi and other healers sang the praises of herbal cures, recommending the *duhn*, or oil, of laurel, wheat, sweet and bitter almonds, mustard and other plants. Wild mint purportedly relieved fatigue when used as a compress and drove out colds if taken as nose drops. "It will also cure the sting of a scorpion," the 10th-century Córdoban doctor promised patients. One look at the fearsome arsenal of surgical tools in al-Zahrawi's *Al-Tasrif* made quick converts to less intrusive herbal nostrums.

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Chemistry, a word derived from the Arabic *al-kimya*, was vigorously promoted, fostering a rigorous routine of trial-and-error experimentation that did not become widespread in Europe until the 18th century with Joseph Priestley, Antoine Lavoisier and other empirical researchers. According to the 10th-century bibliographer Ibn al-Nadim, Arab chemists manufactured waterproof fabrics, invisible inks and mosquito repellents. Around the same time, the Fatimid caliph al-Mu'izz designed a primitive pen with a self-contained ink cartridge nearly nine centuries before the Romanian student Petrache Poenaru invented the fountain pen in Paris in 1827.

The distillation of rosewater and other perfumes evolved into a Muslim specialty, with scents used medicinally to treat migraines, epilepsy and melancholy. In *Kitab kimya al-'utoor w' al-tas'idat (Book of the Chemistry of Perfumes and Distillations)*, the ninth-century scientist Abu Yusuf al-Kindi lists formulas for preparing some 107 perfumes.

In his survey of optics, the 10th-century Baghdad scholar Ibn Sahl observed that light passing through crystals, water and other translucent substances slows down and is bent at different angles according to the density of the material—the basic principle of refraction. According to Rashed, this was reformulated in the 17th century by Dutch scholar Willebrord van Roijen Snell and French mathematician René Descartes as the Snell-Descartes law, or the law of sines. In the early 14th century, more than 300 years after Ibn Sahl, Maragha astronomer-mathematician Kamal al-Din al-Farisi experimented with a glass sphere filled with water to analyze the way sunlight breaks into the spectrum colors of a rainbow.

This page from a 14th-century copy of Avicenna's five-volume *Canon of Medicine* describes several internal organs, as well as the skull and bones. The *Canon* was a compilation of Greek and Islamic medical knowledge.

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The 12th-century Persian physicist Abdur Rahman al-Hazini incorporated Archimedes' findings on the density, buoyancy and specific gravity of objects to perfect "the balance of wisdom," an ingenious scale that resembled a miniature Calder mobile. Originally invented by Abu Hatim al-Isfizari, the device consisted of five hanging trays, one of which was immersed in water to verify precise amounts of gold, silver and other precious metals in coins, jewelry and other materials.

Even as gold and silver mining expanded, the fabrication of artificial rubies, sapphires and other gems grew into a lucrative industry. Poring over the works of Egyptian and Greek alchemists, a handful of Muslim scientists employed their expertise in minerals to dabble in the elusive quest for an elixir, a magical "philosopher's stone," capable of transforming lead to gold. All failed, of course. The eighth-century Persian scientist Jabir ibn Hayyan (Geber in the West), however, turned these experimental dead ends to advantage, concocting an array of previously unknown compounds, including sulfuric acid, caustic soda and nitric oxide, Djebbar explains.

Far more useful than the alchemists' hunt for gold were al-Biruni's pioneering treatises on mineralogy and geology.

In one work, the Persian scholar, who spent much of his career in Ghazni in Afghanistan, asserted that the desert was once covered by the sea. He supported this controversial thesis with detailed descriptions of perfectly preserved fossils of fish and other aquatic creatures, paving the way for paleontology.

Despite centuries of innovation, Islamic science ultimately went into an irreversible decline with the eclipse of Arab political and economic power, marked in the West by the fall of Granada in 1492 to the Castilian monarchs Ferdinand and Isabella, and in the East by the muscular expansion of the Ottoman Empire in the 16th century under Süleyman the Magnificent. But this slide into decadence was a slow process.

Surprisingly, perhaps, the Crusades in the 12th and 13th centuries did more to energize Muslim science than retard it, according to Rashed. (See "Lines of Transmission," page 10.) "The Crusades encouraged Muslims ... to find out the secrets of their enemies' forces," he contends.

The first crippling blow to Islamic science occurred with the Mongol invasions, culminating in the devastating sack of Baghdad in 1258, when two million Muslims were massacred, libraries, laboratories, hospitals and the landmark House of Wisdom were destroyed, and the Tigris ran red with the blood of scholars and black with the ink of their books. "Even after the Mongol invasions, there was still a substantial amount of scientific investigation," Rashed observes, "but scholars had to spend more time and energy preserving knowledge instead of pushing ahead with new explorations."

Another long-term reversal began in the 15th century, as Portuguese and Spanish navigators in heavily armed vessels exploited sea-trade routes between East and West. The slow-moving caravans of the Silk Road were gradually abandoned, breaking the Arab monopoly on commerce with the Orient and further undermining scientific progress, according to Rashed.

Top: A painting of constellations adorns the ceiling of the famous Ulugh Beg Observatory in Samarkand, Uzbekistan, which takes its name from its founder, the grandson of Tamerlane, who inaugurated it in 1420. Right: Astronomers study the moon and the stars in this Ottoman miniature dating from the 17th century.

"Arabic science had arrived at a critical turning point where a cognitive revolution was needed in order to continue," the French science historian explains. In mathematics, for example, complex equations became so cumbersome they required 50 pages to articulate. "Creating new symbols to condense these equations required a conceptual leap that's possible in a society in expansion, but not in a society in decline," says Rashed.

With the rise of Ottoman hegemony, the heyday of Islamic science drew to a close, he argues, since Turkish rulers were far more interested in pursuing military goals and piling up layers of bureaucracy than in encouraging research.

But the lessons of Islamic science have yet to be fully appreciated, even in the Arab world, Audouze maintains, where the unprecedented accomplishments of generations of medieval scholars should inspire contemporary Muslims to rebuild the foundations for a new round of discoveries.

"Science only develops in cultivated societies where the economy and commerce are in good health," says the French astrophysicist. "And it creates a virtuous circle where the economy favors science which in turn generates profits and wealth of all kinds, spiritual as well as material." ⊕

Paris-based author **Richard Covington** writes about culture, history and science for *Smithsonian*, *The International Herald Tribune*, *U.S. News & World Report* and the *London Sunday Times*. His e-mail is richardpeacecovington@gmail.com.

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The Third Dimension

WRITTEN BY RICHARD COVINGTON
PHOTOGRAPHED BY THORNE ANDERSON

Like a kid in a toy store, Fuat Sezgin, still spry at 82, can barely suppress his enthusiasm as he shows off the 800 exhibits that fill the museum of Arabic–Islamic science he's built up in Frankfurt over more than two decades. This little-known treasure house of astrolabes, water-lifting machines, automatons, globes, maps, clocks, balances, weapons, surgical tools and astronomical and architectural models is unequalled in the world.

Above: Dr. Fuat Sezgin, 82, is framed by the rings of an armillary sphere in his Institute for the History of Arab–Islamic Science in Frankfurt. He established the institute in the late 1970's after winning Saudi Arabia's King Faisal Prize for science. Left: The institute is located in a villa in a quiet neighborhood in Frankfurt. It houses the most comprehensive collection of texts on the history of Arabic–Islamic science in the world, and contains more than 800 replicas of scientific and engineering innovations.

"Wonderful, wonderful!" the exuberant Turkish-born science historian says with a chuckle as I activate a 2.3-meter-tall (7'6") clepsydra, or water clock, a brightly colored Rube Goldberg contraption that tells time. Every half-hour, enough water fills a floating basin inside the stomach of a wooden elephant to cause the basin to sink, pulling strings that release a ball that rolls out of a latticework tower into the mouth of one of a pair of joined serpents. Under the weight of the ball, the heads of the serpents fall, raising their tails; this simultaneously starts a scribe writing and triggers a figure in the tower to lift its left hand on the half hour, its right hand on the hour. Strings attached to the rising tails also raise the basin back to the floating position to start the process over again as a drummer seated atop the elephant's head smartly taps out two beats and the ball clatters into a barrel. Ta-da! Who said science couldn't be silly?

Part Ali Baba's cave, part science fair, the museum occupies two floors of a stately, three-story villa on the grounds of Johann Wolfgang Goethe University. It contains very sophisticated toys indeed, modern reproductions of ancient instruments. Some were fashioned by Mahmut Inci, a Turkish-born designer who makes prototype scale models for Mercedes Germany. Swiss clockmaker Martin Brunold fabricated a number of the astrolabes, and Ayman Mohammed Ali Ibrahim, an instrument-maker in Cairo, created others, employing traditional techniques that eschew chemical solvents and electrical tools.

The collection gives science a three-dimensional reality, making it immensely easier to visualize complex concepts that are well-nigh unfathomable on the printed page. Studying an elaborate model of a waterwheel powering a six-piston pump, a device invented by the 16th-century Arab engineer Taqi al-Din, I finally understand the design, which had left me mystified when I originally read about it.

"*Now* I get it," I blurt out to Sezgin in a "Eureka!" moment. Beaming, the white-haired professor gives me a knowing nod and moves on briskly to an ingenious steam-powered turnspit for roasting meat, also invented by the prolific engineer.

"A hundred years after Taqi al-Din created this simple steam engine, Italian designers put wheels on it to fabricate a rolling chair that they presented to Kangxi, the 17th-century Chinese emperor," Sezgin explains.

The Indiana Jones of Islamic manuscripts, a tireless bibliographer who has tracked down more than 400,000 texts from Oxford to Oman and Kashmir in half a century of passionate research, Sezgin has made the propagation of Muslim science a lifelong crusade. When he became the first recipient of Saudi Arabia's King Faisal Prize for science in 1978, he persuaded Jaber al-Ahmad al-Jaber Al Sabah, the amir of Kuwait, to purchase the villa that now houses the museum and the Institute for the History of Arabic–Islamic Science, which Sezgin created at the Frankfurt university. He also donated his entire prize—200,000 marks (around $97,000 at the time, approximately $290,000 today)—to the institute and persuaded government ministers from Saudi Arabia, the United Arab Emirates, Qatar, Bahrain, Jordan, Syria, Libya, Tunisia, Algeria and Morocco to help finance its operation.

Sezgin's original notion for the museum grew out of a determination to make it easier to comprehend hard-to-picture text descriptions of scientific instruments. The first exhibit was a model of al-Jazari's animal-powered machine that used waterwheels, gears and pumps to raise water. The idea was a hit: From the 20 exhibits he had initially imagined, the museum has mushroomed to display some 800 pieces for select groups of students, scholars, scientists and diplomats—a total of around 4000 visitors a year. For most guests, the breadth of the collection comes as a dazzling surprise.

"Muslims themselves do not really know the extent of their own contribution to European science and the Renaissance," laments Sezgin, surrounded by floor-to-ceiling books in his light-filled office. "What little they do know about the subject they owe to the work of European Orientalists who started researching Islamic science in the 19th century." (See "Lines of Transmission," page 10.)

Opposite: **Galleries at the Institute for the History of Arab–Islamic Science are packed with reproductions of astronomical and navigational instruments.** This page: **The water clock model at the institute** (below) **tells the time, and fascinates anyone watching, with a series of intricate, hydraulically driven movements. It mirrors the Elephant Clock from al-Jazari's *Book of Knowledge of Ingenious Mechanical Devices*** (above), **written in the early 13th century.**

Sezgin has certainly made a valiant effort to spread the word—many words, in fact. His institute publishes a huge booklist comprising around 1300 academic treatises and monographs written in German, English, French and Arabic on a wide range of subjects, including geography, mathematics, medicine, astronomy and physics. Sezgin himself is the author of the encyclopedic 12-volume series *Geschichte des arabischen Schrifttums (History of Arabic Literature)*, which covers many manuscripts on Muslim science. At a ceremony in Tehran in February 2006, he won the Iranian World Prize for Book of the Year for the French version of his five-volume work *Science et Technique en Islam*, which provides a beautifully illustrated catalogue of all the objects in the institute's museum: (German and French versions are available under the heading "Natural Sciences of Islam" at www.uni-frankfurt.de/fb13/igaiw. English, Turkish, Arabic and Persian translations are in various stages of preparation.)

"When the Iranian president asked me for his own personal copy, I gave him one," the professor explains, "but I made sure to emphasize the debt Islamic science owed to the French and German Orientalists."

Everywhere he travels in the Muslim world, Sezgin finds an overwhelming curiosity about the achievements of medieval Arab and Muslim scholars. After a series of lectures in Istanbul, he received some 200 letters from people thanking him for opening their eyes to Islamic science. In Cairo, local newspapers report on his lectures because there is so little knowledge about the subject. "To the Egyptians, ancient Muslim science is almost breaking news," he says.

Tucked away in a quiet, leafy neighborhood about a 1.5 kilometers (1 mi) from downtown Frankfurt, the institute is a world away from the high-powered financial centers that the city is famous for. Inside, there is a rarefied aura of scholastic tradition, a feeling that here an essential chapter of global civilization is being preserved and passed on. Lining the stairwell are engraved portraits and vintage photographs of such revered Orientalists as Carl Brockelmann and Eilhard Wiedemann, music specialist Henry George Farmer and, crucially for Sezgin, Hellmut Ritter, his life-changing mentor at Istanbul University.

UPPER: METROPOLITAN MUSEUM OF ART / ART RESOURCE

Upstairs in his office, the professor recollects how Ritter, one of the world's leading Orientalists and a famously demanding teacher who insisted that students learn a new language every year, took the 19-year-old aspiring engineer aside one day and recommended that he broaden his background in mathematics and physics by reading the works of al-Khwarizmi, Ibn Yunus, al-Biruni and al-Haitham.

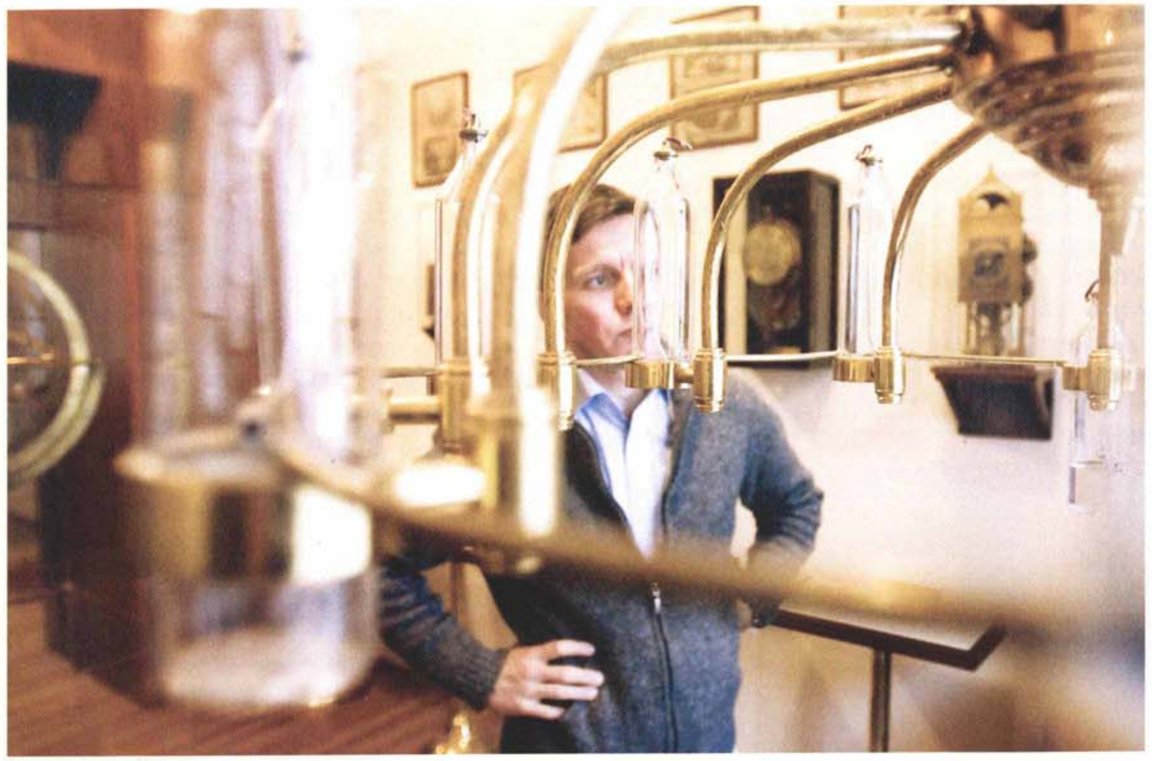
"I had never heard of them," Sezgin recalls with a laugh. "But I stayed up all night poring over their books, ones Ritter had lent me, and the next day he took me to Topkapı Saray library to show me al-Jazari's *Kitab fi ma'rifat al-hiyal al-handasiyya (The Book of Knowledge of Ingenious Mechanical Devices)*. I decided right then and there that [the history of Muslim science] was the research I wanted to dedicate my life to."

In 1960, Turkish generals overthrew the ruling Democratic Party. Even though Sezgin had been very little involved in politics, he was among 147 academics dismissed from Istanbul University in the wake of the coup. Disgusted by the new regime, the 36-year-old professor left the country voluntarily to take up a position as a visiting lecturer of natural science at the University of Frankfurt.

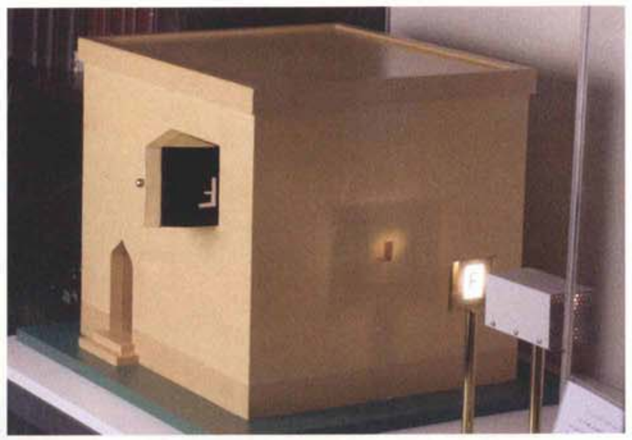
Shortly before leaving Istanbul, Sezgin remembers telling one of his Turkish colleagues of his ambition to compile a bibliography of all the manuscripts in existence on Islamic science. "Impossible," sniffed the man. But Sezgin set out to prove him wrong, devoting more than three decades to the search, uncovering manuscripts in England, Europe, Africa, Russia, Turkey, the Middle East and India. Although he has not traveled to the United States, the Frankfurt scholar has drawn on catalogues from American libraries and private collections for manuscript listings.

After locating more than 400,000 texts, if Sezgin hasn't found all the medieval Muslim scientific writings extant, he probably hasn't missed too many. In his opinion, the most important manuscript he discovered was a copy of a landmark map drawn up for the ninth-century caliph al-Ma'mun. He stumbled across it in 1984, in a 1340 encyclopedia at Istanbul's Topkapı Library as he was making a facsimile of the book.

"Ma'mun's map was a giant step forward," Sezgin explains. "It gives the first really accurate representations of longitude and the circumference of the Earth." For example, where Ptolemy estimated the distance from the Canary Islands—then regarded as the westernmost point of the world—to the eastern shores of the Mediterranean as 63 degrees of longitude, al-Ma'mun's cartographers calculated a substantially smaller figure that is only two or three degrees off



Above: **Through a feat of engineering, 12 oil lamps burn in succession to create an elegant "fire clock."** Right: **The model of the *camera obscura* on display at the institute is based on an explanation by its 11th-century inventor, Ibn al-Haitham. The device was an early progenitor of modern photography devices.**



the true 50-degree measurement. They also depicted the Atlantic and Indian Oceans as open bodies of water, not land-locked seas as Ptolemy had done.

Back down in the museum, Sezgin shows me a model of al-Ma'mun's globe, vividly painted in gold and blue with red bands indicating mountain ranges and thin green lines for rivers. Nearby is a copy of Muhammad al-Idrisi's 12th-century world map, first engraved for Roger II, the Norman king of Sicily, on a ponderous 135-kilogram (300-pound) silver plate two meters (78") in diameter. Although the later map distorts the known world by squeezing land masses and oceans into seven equal climatic zones, it provides considerably more detail on northern Europe, northern Asia and the islands of what is now Indonesia.

Among the institute's 25 elegant compasses made of wood and brass, with magnetized iron needles, perhaps the most historically significant is the simple copper ring with Arabic lettering designed by Ahmad ibn Majid, the great Arab navigator. According to Sezgin, Ibn Majid was the first to mount a magnetized needle on a revolving support above the compass face. Earlier, the professor had eagerly hauled out a copy of one of Ibn Majid's maps, probably similar to one employed on Vasco da Gama's 1498 voyage from East Africa to India, and marveled over its accuracy: It pegged the distance between Africa and Sumatra to within 40 minutes of a single degree of longitude, off by the equivalent of around 74 kilometers (46 mi).

"Eighty percent of the history of cartography until the 18th century dates from the medieval Islamic period," Sezgin asserts. "Only 20 percent came from the ancient Greeks and from later European sources." As proof, he lays before me copies of Chinese and Korean maps that use Arab, not European, place names, and a 1669 French map by Nicholas Sanson that also recycles Arabic longitudes and latitudes. Sanson's map repeats a mistake al-Ma'mun had made about the location of Balkh, in northern Afghanistan, 800 years earlier. Since Muslim cartographers had corrected the error by the 16th century, it is clear that Sanson, working more than a hundred years later, was copying al-Ma'mun's original map, Sezgin says.

Wandering through the museum provides an eye-opening course in eight centuries of Muslim science and Europe's liberal appropriation of Islamic discoveries. In one room are 10 instruments that the 16th-century Danish astronomer Tycho Brahe modeled on instruments from the 13th-century Maragha observatory in northwestern Persia. Among the dozens of gleaming brass astrolabes and equatories—related instruments used to determine celestial longitudes—is one designed on an Arab model by Geoffrey Chaucer, the 14th-century English author of *The Canterbury Tales*, to instruct his son in astronomy.

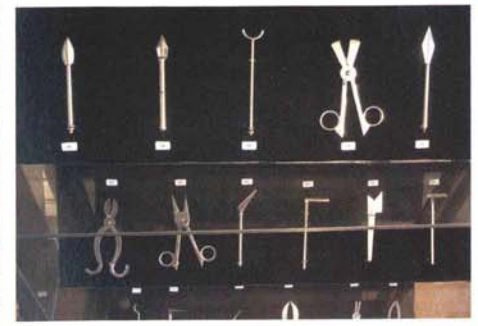
Muslim clocks were some of the most ingenious ever created. One extraordinary reproduction in Sezgin's museum, modeled after an original timepiece from 13th-century Toledo, has hands that move as mercury shifts from compartment to compartment around a wheel. The steadily moving weight of the mercury rotates the wheel through a complete cycle in 24 hours. In addition to showing the hours and sounding them with bells, the clock face represents an astrolabe that indicates the position of the sun and stars. More than three centuries later, in 1598, Attila Parisio, an unscrupulous Venetian watchmaker, wrote a book claiming that he had invented the device. And in 1656, the Campani brothers presented a similar clock to Pope Alexander VII, no doubt omitting to mention its Muslim origins.

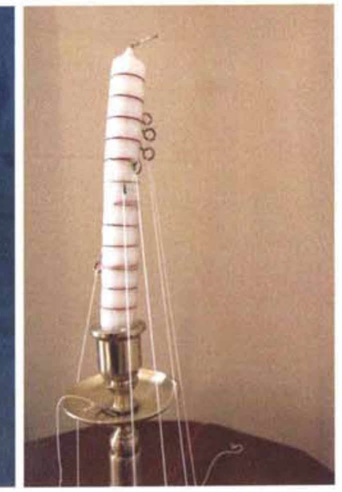
Elsewhere in the museum is a delicately incised 12th-century brass balance with a miniature bowl at one end that drips water with such precise regularity that the counterweight at the other end tracks time in minutes. "This was unheard of in the history of science," marvels Sezgin. "The Greeks could mark time in 15-minute intervals, but no one before had managed to divide it into minutes."

Amid cases holding pear-shaped alembic jars and a cylindrical brass tower sprouting glass retorts with long curved necks, used to distill rosewater, is a 1.5-meter-tall (5') still with coiled pipe running through cold-water basins. It is a reproduction of a 16th-century German apparatus that was modeled after a design by the 10th-century Andalusian doctor Abu al-Qasim al-Zahrawi (known as Abulcasis in the West).

Anticipating Leonardo da Vinci's flying machine by more than 600 years, the Córdoban polymath Abbas ibn Firnas concocted a rudimentary glider in the ninth century that is represented in the museum with leather straps and cloth wings. Looking more like a contemporary hang-glider than Leonardo da Vinci's design, whose weight kept him Earth-bound, Ibn Firnas's glider managed to stay aloft for a few meters, Sezgin assures me, though its 70-year-old designer later died of back injuries suffered during his crash landing.

Despite his irrepressible energy and inveterate optimism, the professor is far from encouraging about the future of Islamic science. "In Turkey, Egypt, Iran and a few other countries in the Middle East, there are a handful of universities offering courses in the history of Muslim science, but so far, the education is not at a very high level because there is a critical shortage of teachers," he complains. Germany and the UK have suffered a decline in interest in recent years, although there is a small surge in programs in the US, he notes. On the plus side, Granada's Science Museum is planning a new





wing devoted to the Arab era, and Turkish cultural officials have recently signed a contract with Sezgin to open a new Muslim science museum at the Süleymaniye complex in Istanbul that will draw on the Frankfurt collection.

"So the interest is there, but it's very difficult work to carry on the history of Islamic science," he says with a sigh. For starters, competent scholars need to be conversant in Arabic, German, French, English and, ideally, Turkish—like Sezgin. When I point out that this is a very tall order, if you also throw in possession of a modicum of knowledge of astronomy, mathematics and other scientific disciplines, Sezgin nods his head in agreement.

"That's why our work here in translating the scientific documents is so crucial," he says. Not to mention the exhibits themselves, which should be viewed by hundreds of thousands rather than a mere 4000 visitors a year. Putting these highly engaging displays on tour could work miracles for educating the public about the depth and ingenuity of the Muslim contribution to science, Sezgin readily agrees, but so far no government, international organization or museum has come forward with a feasible plan—with the possible exception of the Turkish project. If the venerable professor is to have any success in his campaign to carry on the long tradition of Muslim scientific scholarship and research, this illuminating intellectual road show should quickly get on the move. ⊕

Clockwise from top: **A display presents replicas of the earliest instruments for eye surgery; a reproduction of a 14th-century candle clock shows how screws released in rapid succession freed metal balls to chime bells in a rough measurement of equal hours; the Muslim compass used in the Indian Ocean around 1500** (right) **had improved on the 32-point compass used in the West at the same time, allowing Muslim sailors to make more precise navigational calculations than their European counterparts; a replica of the globe commissioned by the ninth-century caliph Ma'mun bears witness to the remarkable accuracy of Muslim cartographers.**

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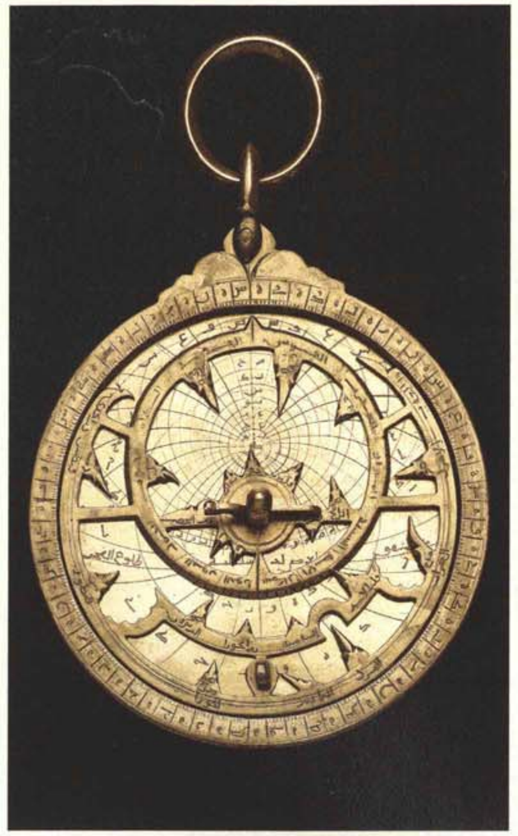
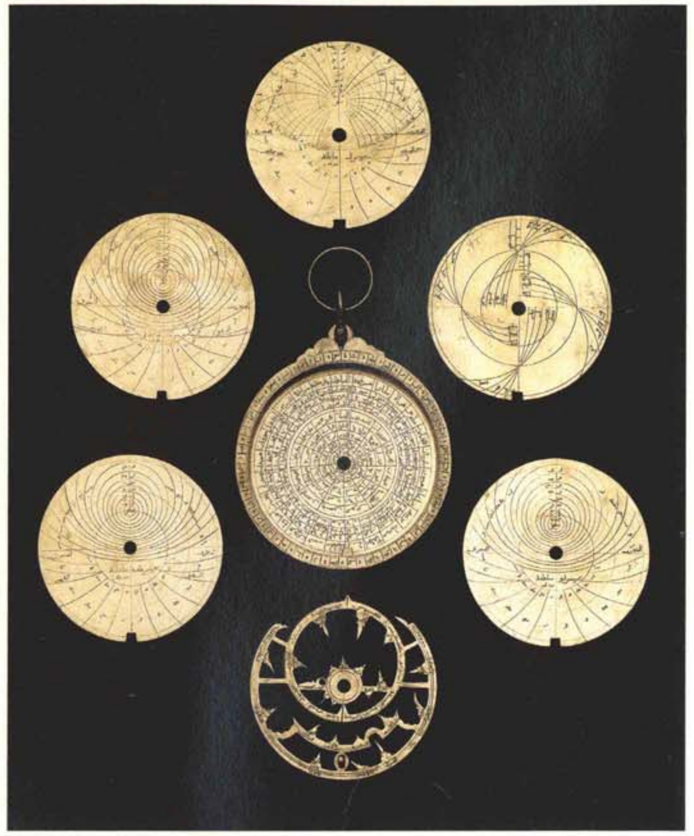
The Astrolabe: A User's Guide

WRITTEN BY RICHARD COVINGTON





The astrolabe at left—shown in working condition and dismantled—was made in Damascus around 1230 by "al-Sarraj the muezzin," according to an inscription. On the mater, the brass plate onto which the other parts fit (at center in right photograph), is a geographical gazetteer of 38 localities, displaying longitude, latitude and direction of prayer for each. It has four different plates for use in different latitudes, plus a replacement. At the bottom is the skeletal rete on which the positions of heavenly bodies are represented by star pointers.

Gingerly, Fuat Sezgin takes the gleaming brass astrolabe out of its display case and hands it to me. "Don't drop it," the science historian warns with an elfin grin. From the 38 astrolabes in the Institute for the History of Arabic–Islamic Science at Johann Wolfgang Goethe University in Frankfurt, I've selected a copy of an elegantly designed model constructed in Muslim Seville in the 13th century. This movable enigma is 16.5 centimeters (6½") in diameter, about the size of a dessert plate, and six millimeters (¼") thick. Front and back are crawling with etched circles, arcs, Arabic lettering and numerals, zodiac signs and dials within dials festooned with tiny hooks and pointers—a beautiful but terrifying astronomy exam.

"That one's stunning, but it sure is complicated," he says with frank, but less than reassuring, cheeriness. "I'll just run you through the basics."

"See that light?" the professor asks, pointing to a ceiling fixture. "Hold the astrolabe up to the light, look along the pivoting ruler on the back and line it up with the light, which is your star," he explains. "Where the ruler crosses a scale that circles the back rim of the instrument, the number shows the altitude, in degrees, of that star above the horizon. You take that measurement and the sun's celestial longitude, using the separate calendar scale on the back, match them up with the star's altitude and the sun's coordinates on the front of the astrolabe, and you can determine the name of the star and its location."

"Got it?" asks Sezgin, as he replaces the instrument in its case. "It just takes some practice," he adds, with a confidence I am very far from sharing.

After hours poring over explanations, watching demonstrations on the Web site of the Institute and Museum of the History of Science in Florence, Italy and fiddling with "The Electrical Astrolabe," a whiz-bang computer simulation created by James Morrison, a retired software engineer from Delaware, I'm still a tenderfoot. But I can now report I know my way around the astrolabe well enough to tell time and even locate a few stars with it.

Based on an ancient Greek concept, the astrolabe is the salient emblem of Muslim science. The 10th-century astronomer Abd al-Rahman al-Sufi claimed it had a thousand uses—a bit of poetic exaggeration, of course. The instrument served chiefly to pinpoint stars; predict sunrises, sunsets and prayer times; find the *qibla* (the direction for prayer toward Makkah); survey land; and cast horoscopes. A simplified version, known as the mariner's astrolabe, was used for navigation.

An endearing but unlikely Islamic legend has it that the second-century Alexandrian astronomer Ptolemy conjured up the astrolabe when he dropped the celestial globe he was studying while riding a donkey. The donkey stepped on the globe and flattened it, inspiring Ptolemy to reproduce the three-dimensional sky on a two-dimensional plane.

NATIONAL MARITIME MUSEUM, LONDON

In fact, an earlier Greek astronomer named Hipparchus from Nicaea (present-day Iznik in Turkey) wrote about the concept of stereographic projection around 150 BC. Although ancient Greek scientists probably created astrolabes, none has survived. The oldest instrument extant, designed by Nastulus in Baghdad in about 927, is now part of Kuwait's national collection.

The most complete collection of astrolabes in the world, with some 136 instruments, is at Oxford University's Museum of the History of Science; the UK's National Maritime Museum at Greenwich has around 70. In the US, Chicago's Adler Planetarium, the Smithsonian's Museum of American History and Harvard University each has extensive collections on display.

Some astrolabes are incomparable works of art. In medieval workshops in Baghdad, Aleppo, Cairo, Toledo, Seville, Istanbul and Lahore—and later in 16th-century Augsburg and Nuremberg in Germany and Louvain in Belgium—metalworkers fashioned pieces of incredible finesse, precision and occasional whimsy, with star pointers shaped like birds' beaks, dogs' heads, even court jesters. One of the most exquisite astrolabes in the Frankfurt museum is a copy of a 17th-century Persian design swirling with filigree ornamentation and incised with geographical coordinates for 46 cities between Baghdad and Balkh in northern Afghanistan.

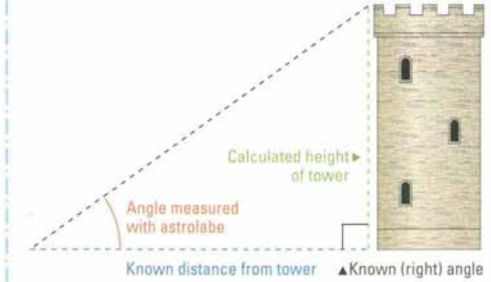
The word *astrolabe* is a Greek–Arabic hybrid that literally means "star-holder," an apt description for a device that indicates the positions of the stars, sun, moon and planets. Essentially, it is a map of the heavens, depicting the apparent movements of celestial bodies in terms of celestial latitudes and longitudes, combined with slide rule-like features that allow calculation.

Although there are spherical astrolabes, the most common is the flat, or planispheric, astrolabe, which consists of four parts. A plate, or tympanum, representing the sky fits into a larger base plate, the mater ("mother" in Latin), which is calibrated in degrees (and sometimes also in hours) around the rim. The rete ("net" in Latin) is a large openwork disk with star pointers; a circle showing the sun's annual path, the ecliptic, is engraved on the rete. (Some astrolabes were also fitted with a clock-like hand on the front called the rule.) On the back is another ruler, the alidade, which pivots on a brass pin that passes through the center of the mater, the tympanum and the rete. All the parts can pivot concentrically in relation to each other.

Because the sky looks different according to one's location on Earth, a person in Baghdad sees constellations in different positions than someone in Cairo, Córdoba or Toledo, for instance, on any given night. To take this shifting sky into account, observers used different tympanum plates for different latitudes. Some planispheric astrolabes were equipped with as many as nine interchangeable plates for latitudes ranging from Zaragosa to Ghana and Sri Lanka. But in 11th-century Toledo, Ibrahim al-Zarqali (known in the West as Azarchel) perfected the *safiha*, a universal astrolabe with only one plate that was capable of making readings at any latitude.

Generally speaking, if you know the time, you can locate virtually any celestial body using the astrolabe. Conversely, if you know the coordinates of the sun or stars, you can tell the time. Say you want to predict the time that sunrise will occur on a certain date. You locate that date on the circular calendar engraved on the back of the astrolabe, line it up with the edge of the alidade and read off the coordinates for the sun's celestial longitude on that date. Then you rotate the rule on the front of the astrolabe so that it crosses that longitude marked on the small ecliptic circle on the rete. You then rotate the rule and the rete together until they intersect on the eastern horizon shown on the astrolabe. You see that the rule crosses a time marked on the rim of the mater: That is the time of sunrise on the date you selected.

Many astrolabes also had "shadow squares" engraved on their backs to enable the observer to measure the height of buildings, trees, mountains and so on. For example, if you know how far you are from the base of a tower, you hold up the instrument and sight the top of the tower along the alidade. Where the alidade crosses the shadow square, you read off the number on the vertical scale as a ratio to the horizontal scale. Using this ratio, you can calculate the height of the tower as a proportion of your horizontal distance from it.



Calculating the height of an object as a proportion of your distance from it, using an astrolabe.

Brought to Europe through Muslim Spain around the 13th century, astrolabes remained popular until the 17th century, when they were supplanted by pendulum clocks and telescopes. The 14th-century poet Geoffrey Chaucer wrote the first treatise in English on astrolabes to teach his 10-year-old son, Lewis, about astronomy. The instruments remain handy devices for understanding time and the heavens, whether you use a cardboard astrolabe or a computer-simulated one.

Terrestrial use of astrolabe:
http://brunelleschi.imss.fi.it/museum/esim.asp?c=500169

Astronomical use of astrolabe:
http://brunelleschi.imss.fi.it/museum/esim.asp?c=500170

Computer-simulated astrolabe:
www.autodidacts.f2s.com/astro/index.html

Laminated-cardboard personal astrolabe:
www.astrolabes.org

Brass astrolabes:
www.astrolabe.ch

LEVIATHANS *of the* MONSOON

WRITTEN AND PHOTOGRAPHED BY ANNA MCKIBBIN

CLINGING TO THE SIDES OF OUR RUBBER BOAT AS IT BOUNCES AROUND ON A SEA OF FOAM, WE GAPE AT THE PERFORMANCE JUST IN FRONT OF US. FOR PERHAPS THE 20TH TIME IN SUCCESSION, OUR VISITOR (above) HEAVES ITS VAST BULK OUT OF THE WATER AND CRASHES BACK DOWN AGAIN, CREATING A WAVE THAT THREATENS TO SUBMERGE US. NEXT IT SLAPS ITS TAIL AND ITS LONG PECTORAL FINS REPEATEDLY ON THE WATER'S SURFACE—A FRENZIED FINALE THAT FLINGS UP SHEETS OF FISHY SPRAY, FORCING US TO SHIELD OUR CAMERAS—UNTIL FINALLY, EXHAUSTED BY ITS GARGANTUAN EXERTIONS, IT TAKES A BOW, LIFTS ITS TAIL FLUKES AND SLIDES NOISELESSLY INTO THE DEEP.

We compare notes, trying to estimate the creature's vital statistics. Acrobatics like this would be impressive if executed by a half-ton trained sea lion, but this is a humpback whale, some 12 meters (39') in length and with a likely weight of around 35 tons. We suspect its friskiness is breeding-related, and soon our suspicions seem to be confirmed: We're just about to restart our engines when an unearthly noise reverberates through our boat. It starts as a deep chainsaw bass, then sweeps up the scale to a shrill chimpanzee whoop. We drop our underwater microphone over the side and record the sound. Our whale is singing, a noise created by forcing air through massive air cavities in its head. Only male humpbacks sing, and they do it only during the breeding season. We're not sure whether this is to discourage rivals or to attract a mate—

Omani and international volunteers in 2000 founded the Oman Whale and Dolphin Research Group, which counts and tracks marine mammals through the waters off the southern Arabian Peninsula.

possibly both. To us, it doesn't sound like much of a love song, but it could help us understand how this whale is related to other whales farther south.

Few people associate the Arabian Sea with an abundance of marine life, but the local wildlife here is keeping our team from the Oman Whale and Dolphin Research Group very busy indeed. We're spending a month on an annual field trip to the remote Hallaniyat Islands, 100 kilometers (62 mi) off Oman's southern province of Dhofar. We hope the trip will help us understand more about the whales and dolphins that inhabit these waters. It's slow and painstaking work, and we're using every research method at our disposal, including recording whale songs and taking DNA samples. Our transport is a 28-meter (93') oceangoing sailing dhow. Her slow speed is ideal for our purposes, and she comes equipped with a small inflatable boat that enables us to get close to any action. Provided, that is, we can find some animals to study.

Locating whales is never an easy task. They're big, but the ocean is a whole lot bigger. One of the techniques we use is to look near their food. Beneath us are underwater cliffs where the seabed plunges from a few hundred meters' depth to more than a thousand (3250'). They're prime hunting grounds for squid and a good place to find the squid's most fearsome predators—sperm whales.

Soon our efforts are more successful than we could have hoped. In front of us an aggregation of sperm whales, perhaps 50 strong, lies "logging" at the water's surface. These are the world's largest predator—giants of the deep, immortalized by the vengeful deeds of Herman Melville's fictional Moby-Dick. They are capable of diving to depths of 2000 meters (6500'), where they stun squid with sonic clicks created in their enormous blunt heads. Now they are basking in the bright sun, taking turns sending up geysers, and then, one by one, lifting their tail flukes for another dive.

We record our encounters on sighting sheets, and the stack of them attached to my clipboard bears witness to our action-packed week: Vast schools of long-beaked common dolphins, 3000 strong, emerge from a pink dawn; smaller groups of Rissos dolphins, their smooth gray bodies heavily scarred by their fierce rivalries, cross our bows; a secretive beaked whale is glimpsed so briefly that the exact species can't be confirmed; four rare blue whales, each the length of two London buses, frolic just offshore; and finally, three further lone humpbacks lure us in with their siren songs and allow us close enough to get a shot at them with our crossbow and biopsy dart. It's a tricky operation requiring a steady hand, but the dart's hollow tip collects genetic material invaluable to our work here.

Right: **A pair of sperm whales—the world's largest predator—swim on the surface in front of the research ship *Sanjeeda*.** Lower: **With a span that can be as much as five meters (16'), the flukes of a blue whale are caught by the camera before slipping below the surface.** Opposite: **A common dolphin calf leaps alongside an adult.**

It's reassuring to know that marine life here is flourishing, but also a little puzzling. These tropical waters are crystal clear, with no sign of the green algae generally needed to support a mass of marine life, which raises the question: Where is all the food coming from? The answer lies thousands of kilometers to the east.

During the summer months, temperatures in Oman's capital, Muscat, climb to a sweltering 50 degrees Celsius (122° F). Farther south in Oman, however, the climate is very different. From the spring equinox through summer, warming air over southern Asia rises, creating a powerful weather system known to us as the southwest monsoon, and the southern Arabian Peninsula grabs a slice of it. Rain-filled mists transform the dusty landscape into a lush garden, while winds whip the sea into a frenzy of foam. During the monsoon, known locally as the *khareef* ("the time of ample rain"), fishermen pull their boats high up the beach and tend to their nets, but the storms that prevent them putting out to sea are vital to the following year's catch.

"It's the strong winds," explains Fergus Kennedy, a marine biologist working with our team. "They stir cold, nutrient-rich water up from the deep, in a process called upwelling. It kick-starts the entire food chain."

This is April, and the khareef is still a couple of months away, but in June these calm, clear waters will be transformed into a green soup, its surface erupting in washes of froth. Kelp forests will spring up among tropical corals, jellyfish will invade the waters in mythic numbers, and fish stocks will be replenished.

TOP AND OPPOSITE, TOP: HANNE & JENS ERIKSEN

WHALE BEHAVIOR

Whales exhibit various types of behavior when they surface. Humpback whales are among the most acrobatic and visible.

Breaching: Scientists aren't sure why whales breach—that is, why they leap out of the water. One theory is that they use the thunderous splash created on impact (which can be heard underwater hundreds of kilometers away) as a means of communication. Or the impact may remove parasites from their skin, or stun prey fish. Whales have been recorded breaching continuously for over 90 minutes, achieving well in excess of 100 leaps.

Lobtailing: A whale "lobtails" when it slaps its tail or pectoral fins on the surface of the water. As with breaching, scientists think lobtailing may be a form of communication—possibly signaling aggression.

Spy-hopping: Whales can sometimes be seen lifting their heads out of the water with their bodies vertical, as if treading water, and this act is known as "spy-hopping." They may do this to familiarize themselves with their surroundings—for example, to look at boats. Powerful individuals can spy-hop with half their body out of the water.

Logging: This term is generally used to describe sperm whales floating horizontally at the surface of the water. In this position, they resemble floating logs (above).

Bubble netting: Although it's an activity we've yet to witness in the Arabian Sea, humpback whales often use a technique called "bubble netting" to catch fish. To do this, a whale will submerge beneath a school of food fish and exhale, blowing bubbles in a circle around the school. The fish move closer together, and the rising bubbles act like a corral so that they can't escape. The whale can then move into the bubble net and surface with its mouth wide open, taking in huge gulps of fish-filled water. Whales often cooperate in using this technique.

The monsoon is also crucial to Dhofar's tourist trade. While the rest of the Peninsula sizzles in Arabia's harsh summer heat, the fresh mists and balmy temperatures of southern Oman pull in tourists from across the region, providing a vital boost to the local economy. However, other visitors lured here by the monsoon have been less welcome.

The Soviet whaler *Slava* was passing through on her way to the Antarctic in 1963 when she first stumbled upon these waters. It was November, the southern-hemisphere summer and the season when the southern polar seas are transformed into a feeding ground for migrating blue and humpback whales. There, the *Slava*'s crew anticipated rich pickings. Their customary route south was through the Strait of Gibraltar and around the west coast of Africa, but this year, the *Slava* took a shortcut through the Suez Canal and the Red Sea. It paid off: The clear, tropical waters of the Arabian Sea revealed an unexpected, astonishing wealth of marine life. Over the next four years, using a blockade of catcher vessels 100 kilometers (62 mi) wide, the Soviets swept the ocean, annihilating virtually every whale in their path and processing their catch aboard the factory ships *Slava* and *Sovietskaya Ukraina*. By the time the International Whaling Commission (IWC) managed to put an end to their covert activities, they had plucked an astonishing 3000 whales from the coasts of Oman and Yemen, including 1294 blue whales and 242 humpbacks.

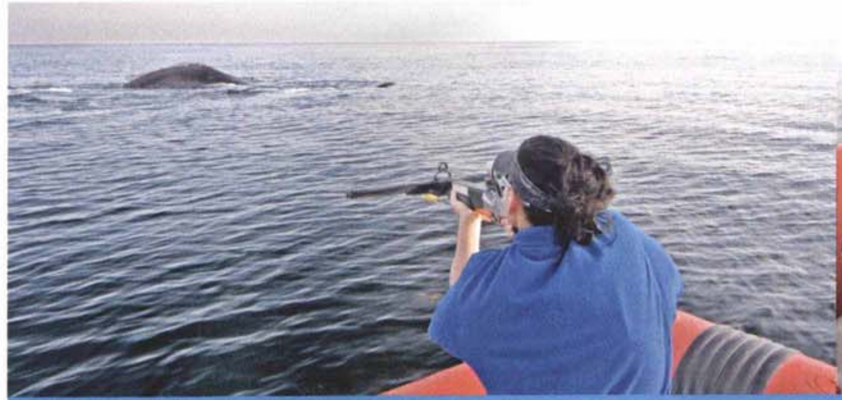
Not until 1986 was a global moratorium on whaling implemented, but by that time an estimated 380,000 blue whales and 200,000 humpbacks had been snatched from the world's oceans. With blue whales now endangered and humpbacks considered vulnerable, much of the work of our Oman Whale and Dolphin Research Group has been focused on trying to work out just how many humpback whales are actually left in these waters. It's a project we've been working on for seven years, and we use a method called "mark-recapture." The markings on each whale are unique to that individual, rather like a human fingerprint; we photograph the tail flukes and dorsal fin of each humpback whale we encounter. With that record, we compile a catalogue of all the whales we've seen, rather like a rogues' gallery.

Back on board the dhow, we compare our photographs of the humpback who performed for us that morning with our database. It's whale number OM01-003, better known to us as "Smooch" because of a kiss-shaped scar at the base of his dorsal fin—and in acknowledgment of his vocal talents. If the truth be told, we're not entirely pleased to see him. The rate at which we re-sight humpback whales provides an estimate of population size, and it's the high number of re-sights of individuals like Smooch that are leading us to a current population estimate of as few as 100 animals. As for blue whales, in the nine years we've been patrolling these waters, we've recorded just seven sightings. Those are sobering statistics when compared with the size of the Russian catch, but our work in this area also suggests that there may be something very special about the survivors.

Humpback and blue whales are baleen whales: This means that, despite their huge size, they feed exclusively on small fish and crustaceans, which they filter from the seawater using comb-like rows of springy, bristle-edged plates in their mouths called baleen, or whalebone. For them to find the vast quantities of food that these whales need to sustain themselves, scientists used to think that they conducted semi-annual migrations, leaving the warm winter breeding grounds of the tropics to converge on summer feeding grounds at the poles. This meant that we should only expect to see whales here in the winter months—yet we were seeing them year-round. Why weren't these whales migrating?

"Oman is in the northern hemisphere, and you'd therefore expect Oman humpbacks to spend the northern hemisphere's summer in the Arctic," explains Gianna Minton, a member of the team who completed her doctoral degree studying these whales. "However, one look at a world map shows the difficulties involved in that sea trip." The route to the Arctic from the Arabian Sea is, indeed, entirely barred by the African and Asian land masses, but the route to the other pole—the Antarctic—is clear. Could the whales instead be making the longer round-trip to feed in the Antarctic instead?

Given that whaling is the cause of their downfall, it is ironic that much of our knowledge of whales comes from whaling data. It took 29 years—and the collapse of the Soviet Union—for the true scale of Soviet whaling in the Arabian Sea to be revealed. But when former Soviet scientists finally broke cover, the catch data they published provided the key to unlocking what Robert Baldwin, author of the leading work on Arabian cetaceans, terms the "Arabian enigma." Minton explains that around half the female humpbacks caught by the Soviets were pregnant, and that "the state of development of the calves suggested that the humpbacks were breeding here between January and May. It's what we'd expect from a northern-hemisphere population, but it meant that they couldn't be traveling to the Antarctic to feed: By the time they'd finished calving, it would be the southern-hemisphere winter."



RESEARCH METHODS

Modern-day whale researchers have a number of tools at their disposal.

Photo Identification: The markings on the tail flukes of a humpback whale are unique to that individual, rather like a fingerprint. By taking photographs, we can build a catalogue of individuals. Counting the rate at which we re-sight them (a practice called "mark-recapture") helps us calculate a population estimate, while identifying the same individual in different locations can shed light on seasonal and annual whale movements.

Line transect sampling: Mark-recapture programs take time to become established. A quicker method of obtaining population estimates uses the number of whales sighted along a given course traced by a boat or an aircraft to calculate a "whales per kilometer" figure. We can extrapolate from this to give an abundance estimate for a larger area.

Acoustic surveys: Whales in different geographical areas have very different calls. Recording these using a hydrophone (an underwater microphone) can help us understand the relationship between groups of whales and whale movements.

Genetic sampling: Analyzing whale DNA can provide basic information such as gender, and it can also help explain the relationship between populations of whales. Researchers gather genetic material using a crossbow (above, left) and small, hollow-tipped biopsy dart (right). In addition, we can also retrieve naturally sloughed-off skin left in the water when a whale dives.

Satellite tagging: Although expensive, satellite tags can help track the position of whales for long periods in open ocean.

It takes patience to catch sight of humpback whale flukes at a distance and angle that allow photo-identification, but with markings as individual as fingerprints, the resulting image allows researchers to both estimate population and compile a record of a single whale's movements.

Adding the Soviet data to our evidence of year-round sightings seemed to suggest only one conclusion: The whales were relying on the seasonal boost of the monsoon to sustain them here for 12 months of the year. They weren't migrating at all.

The results from our other research methods point to the same conclusion. Humpback whales within any given geographic area tend to sing the same song, and this can vary greatly from one population to another. On initial analysis, the songs of Oman humpbacks have little in common with adjacent populations off the east coast of Africa, suggesting that those populations don't come into contact with each other, which they might if the Oman humpbacks were migrating. Results of DNA analysis further suggest that the Oman whales are non-migrating residents of the Arabian Sea.

It's a finding that could have important implications for conservation. Oman humpbacks and blue whales, it seems, are as unique as their South Arabian habitat, and the monsoon that once lured whalers here could help conserve the surviving population. At present, the Indian Ocean is a sanctuary from whaling—a measure introduced by the IWC in 1979—but current pressure for the reintroduction of commercial whaling means that it may not retain this status in the future. If the Oman humpbacks and blue whales constitute an isolated population, then we might be able to argue for the protection of at least those species of whales in order to preserve global genetic diversity.

Our own time in the waters off Dhofar is at an end. The whales may stay here year-round, but we cannot. The winds have started to pick up, signaling the start of the khareef. We pack up our equipment and prepare to return to Muscat. We'd like to stay longer, but we know that the gales that evict us from the sea will sustain these leviathans until we return again. ⊕

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The Skill of the Two Hands

WRITTEN BY CAROLINE STONE
PHOTOGRAPHED BY ALEXANDER STONE LUNDE

"Money vanishes, but the skill of the two hands remains." So says a favorite proverb on both sides of the Mediterranean; it surely reflects why girls throughout that region were taught to weave and to use the needle.

As a result, some of the most charming embroideries were produced to embellish homes, demonstrate skills, to while away otherwise idle hours and provide the pleasure of self-expression. Among them are the embroideries from throughout the Ottoman Empire, known as *işlemeler* (pronounced eesh-lem-eh-LAIR) and often referred to, rather loosely, as "Turkish towels."

The earliest surviving Ottoman embroideries—"Ottoman" is more correct than "Turkish," since they come from different parts of the empire—were almost certainly made professionally or in the palace workshops at Topkapı Palace in Istanbul. They show bold, stylized repetitive designs: trellises, medallions, pomegranates, carnations and, of course, tulips. These, from the 16th century, held a special place in Ottoman gardens, poetry and art, so much so that that period was known as the *Lâle Devri*, "the tulip age," and the passion spread to Europe.

In the past, embroidery was a relatively cheap means of decorating cloth, and embroidery designs often imitated those on brocades and other more expensive woven textiles. The early Ottoman pieces with a pomegranate design may have been copied from luxury textiles from Italy and Spain. In a similar way, patterns from Chinese silks were adapted in Iran and moved west from there.

As well as large, formal embroideries, which have much in common with the *suzanis* still produced in Central Asia, there were smaller pieces, often far more varied and personal, that were made at home. Almost certainly, they existed before the 16th century, but no examples that old have survived. Marco Polo mentions women embroidering in the city of Kirman, then under Tatar rule:

> The gentlewomen and their daughters are adepts with the needle, embroidering silk of all colors with beasts and birds and many other figures. They embroider the curtains of nobles and great men so well and so richly that they are a delight to the eye. And they are no less skillful at working counterpanes, cushions and pillows.

Around 1550, a traveler from Genoa, whose name has been lost to us, described an audience with the Haseki Sultana, the mother of the sultan's sons. His account includes an early mention of the Ottoman custom of offering a guest a tray of beautiful textiles on departure. (See box, page 35.) The sultana was almost certainly Hürrem, also called Roxelana, the wife of Süleyman the Magnificent, who was famous even in Europe for both beauty and wit. She was an ex-slave, most probably of Russian origin, and it is in her tomb and in that of her son, the Şehzade Mehmet, who died in 1543, that the oldest surviving examples of these more personal embroideries have been found: five handkerchiefs.

A century later, the great Italian traveler Pietro della Valle wrote, "We find it hard to believe in our country that work on white cloth is held in such esteem and value in Turkey, and that they make such a lot of it. The reason is that the women are usually kept shut indoors and that they have no house work to do, unless they are employed to do something, so they pass their time at embroidering white cloth."

Down the centuries, Europeans commented on the quantity and quality of Ottoman embroideries. From the Hapsburg

Top: A posy of flowers, symbolizing happiness and shown here in a very stylized vase, was a favorite embroidery motif. The original colors of this 19th-century piece, worked in silk with touches of metal thread on hand-woven linen, seem to have faded with time, as is often the case. Right: This man's sash end, with an almost standard design and color scheme, was probably professional work. Done in silk on heavy linen, it dates to the early or mid-1800's.

court in 1598, the Archduchess Marie-Christine sent her mother a ribbon, noting in the accompanying letter that it was "only a simple ribbon and plain, but am sending it because I know well enough that Your Highness likes Turkish things. My Turks have sewn it." Turkish embroideresses

Embroidery was a socially approved activity that gave women scope for creativity.

(bulya) were highly valued at the Hapsburg court and in fact throughout Hungary: The loan of one to help prepare a trousseau or some other special piece of work was a common request between friends. In 1660, one young noblewoman had no fewer than seven bed-sheets embroidered in the Turkish manner. Later, sashes and handkerchiefs also became popular.

The quantity of embroidery produced is not surprising. In a society where slaves and servants performed the harder domestic tasks, where women were sequestered and rarely went out, where they were often illiterate, and where music, drawing and painting were not conventional accomplishments, there was plenty of time. Embroidery was thus a socially approved activity that gave scope for a measure of creativity. It was one of the rare permitted areas in which a girl could express herself—and even attract attention. Her embroideries would be admired on outings to the *hammam*, or baths, proofs that she was skilled and hardworking. They would be shown off as part of her future dowry, and when she married, they would join other family treasures to decorate her house. In times of hardship, needlework could be sold for cash, and a woman could take on such work to support a family.

This finely embroidered piece, in silk on linen, was probably part of a bath set and dates to the 1700's. It features a classic design of stylized flowers, with colors reminiscent of Iznik ceramics and certain types of Turkish and Daghestani carpet. Such textiles occasionally made their way to Europe and appear in paintings of the period.

In his memoir *Portrait of a Turkish Family*, which recalls Istanbul of the early 20th century, Irfan Orga describes his elegant mother, always at home, always working at her beautiful embroideries. He suggests that they were her great comfort, and that they were an outlet for the creativity and emotion that she was not free to express elsewhere. After the disappearance of his father and uncles in World War I, the family was left penniless, and she used her embroidery skills to keep them from starving. Versions of this story must have been repeated thousands of times down the centuries.

Nearly 300 years earlier, in 1638, Evliya Çelebi wrote in the *Seyahatname*, compiled on the orders of Murad IV, a vivid description of Istanbul's guild procession. Every craft is mentioned individually:

> The handkerchief-makers *(yaghlikjián)* are one hundred men with sixty shops. The first lady who worked a handkerchief was Balkis, the Queen of Saba [Sheba], and wife of King Salomon. In the Prophet's time, Selman, the Persian, sewed handkerchiefs and sold them. They [the Guild] exhibit…a show of all sorts of handkerchiefs.

Yağlık is often translated as "napkin," and these shops presumably wove and sold the basic article, and perhaps the handsome, block-printed handkerchiefs in dark colors used by men throughout the Ottoman Empire when taking snuff—especially after Murad IV first banned smoking and then made smokers liable to the death penalty.

Left: In the Balkans, as in the Greek islands, traditional patterns survived in embroideries. In this 19th-century piece, the archaic-looking bull and bird, probably a cock, are worked in silk on very heavy linen woven in an elaborate diapered pattern, probably intended for a wedding. Needle lace was used to join the panels. Right: The "trefoil" pattern on the girl's sash end is really a stylized spray of flowers. This 19th-century piece is worked in silk on linen.

Further on in the procession Evliya mentions the embroiderers:

> The embroiderers of handkerchiefs [*nakkáshan*] are twenty-five men with twenty shops. Their patron is Serraj-ud-din…. His tomb is near Damascus. They embroider with variegated silk cushion-cloths, handkerchiefs, towels, shirts and sheets. My mother was famous in this handicraft. They pass embroidering.

This is one of the very few times in his chronicle that Evliya Çelebi mentions a female member of his family: Clearly the detail was an important one. His catalogue of the crafts of the city enumerates the men in each one, and it is striking how few were producing handkerchiefs, as opposed to, for example, the 800 men engaged in the production of belts. This was because handkerchiefs were generally made in homes, whereas belts, particularly those used for uniforms or embroidered with gold, were typically made by professionals. The same can be said of the *dival* embroidery worked in metal thread on the sumptuous velvet robes worn by both men and women, and also on horse trappings, slippers, sheaths, pouches, covers and other items still made, especially in North Africa, using classic Ottoman patterns.

The Ottoman Empire had strict sumptuary laws, which meant there was considerable standardization of dress in the different regions. Uniforms were made both in Istanbul and Bursa and in workshops in Janina (in modern Albania). The effect of these regulations, and the powerful influence of the court, meant that patterns spread across the empire. Similar designs are thus found in both East and West, although specialists now recognize certain distinctions between Balkan *(rumeli)* and Anatolian designs. One major difference is that the pieces made by the Christians under Ottoman domination are more likely to have animals or even figures—for example, the beautiful ships from the Greek islands, or the elaborate covers and curtains for the marriage bed with stylized figures representing the bride and groom. Towels from the Balkans are often woven in elaborate geometric patterns and then worked with bulls or birds, a motif found again in Greece.

Handkerchiefs, napkins and other embroideries on linen (or later muslin) were made by women at home either for domestic use or, as several travelers describe, for sale by Jewish or Christian women who had more freedom of movement, and who could peddle them to the houses of the wealthy or in the bazaar.

The European Discovery of the Modern Bath Towel

The towels in Ottoman hammams were much commented on by foreign visitors, who were struck both by the plain linen towels, made up of three or four narrow strips and richly embroidered at the ends, as well as by the towels woven with a loop pile, so that they were much more absorbent than normal flat-weave material—in other words, modern "Turkish towels." Pietro della Valle, writing in the 1620's, praised not only the embroidery, which he said would delight the women of Rome, but also the pile towels and the bathrobes, which were something new in his experience:

"Nor must I omit mentioning a certain kind of cloth produced here (and made best of all in Salonika, where I have already arranged to be well furnished with it), which, as woven, has a pile on one side, namely the part of the lining; with the long thick nap on the fabric just like our velvets; and from this sort of cloths they make various kinds of towels, large and small, and certain other items, not shirts but rather like jackets open in front, with loose sleeves, to put on over the naked skin when one comes out of the bath; for with this pile, when it is inside next to the skin, these garments dry one at once quickly and well all over. This is truly marvellous after bathing, either swimming or in the hot bath, and for women when they wash their hair, and deserves to be imitated in our country, though how I do not know."

This embroidery presents a classic Ottoman image of peace and civilization: trees—commonly cypresses—flowers and a pavilion beside water, the latter a very important symbolic element. It was done in silk on handwoven linen in the 19th century.

A Visit to the Wife of Süleyman the Magnificent

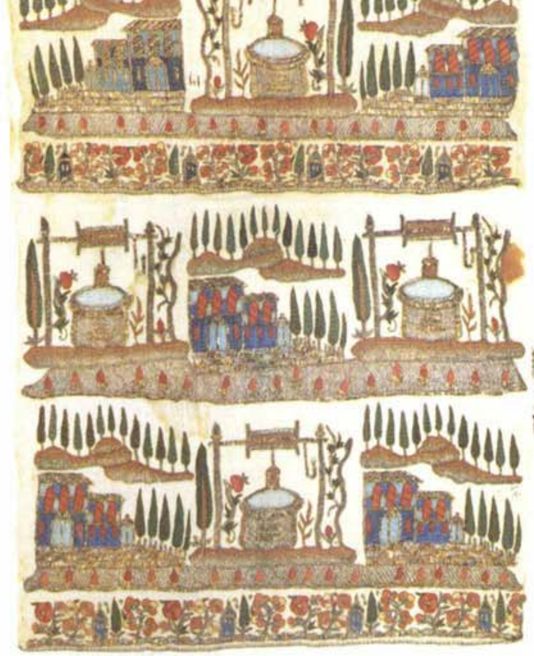
When I entered the kiosk in which she lives, I was received by many eunuchs in splendid costume blazing with jewels, and carrying scimitars in their hands. They led me to an inner vestibule, where I was divested of my cloak and shoes and regaled with refreshments. Presently an elderly woman, very richly dressed, accompanied by a number of young girls, approached me, and after the usual salutation, informed me that the Sultana Asseki was ready to see me. All the walls of the kiosk in which she lives are covered with the most beautiful Persian tiles and the floors are of cedar and sandalwood, which give out the most delicious odor. I advanced through an endless row of bending female slaves, who stood on either side of my path. At the entrance to the apartment in which the Sultana consented to receive me, the elderly lady who had accompanied me all the time made me a profound reverence, and beckoned to two girls to give me their aid; so that I passed into the presence of the Sultana leaning upon their shoulders. The Sultana, who is a stout but beautiful young woman, sat upon silk cushions striped with silver, near a latticed window overlooking the sea. Numerous slave women, blazing with jewels, attended upon her, holding fans, pipes for smoking, and many objects of value.

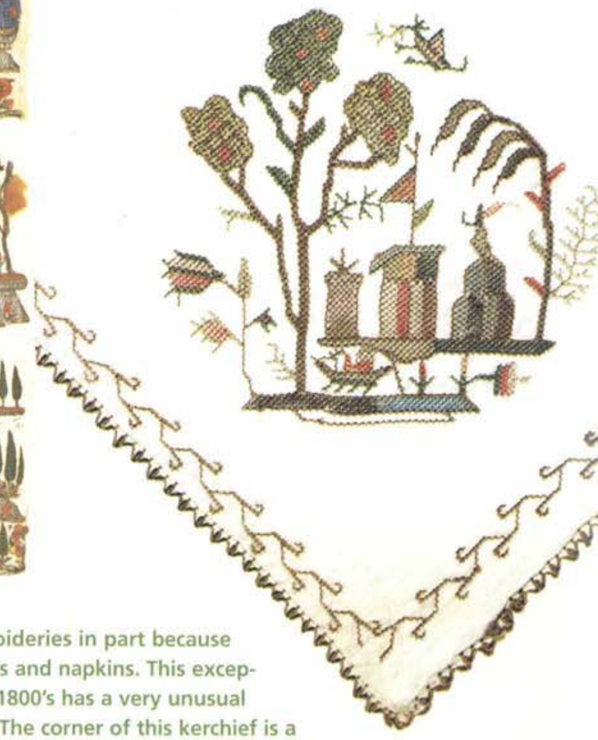
When we had selected from these, the great lady, who rose to receive me, extended her hand and kissed me on the brow, and made me sit at the edge of the divan on which she reclined. She asked many questions concerning our country and our religion, of which she knew nothing whatever, and which I answered as modestly and discreetly as I could. I was surprised to notice, when I had finished my narrative, that the room was full of women, who, impelled by curiosity, had come to see me, and to hear what I had to say.

The Sultana now entertained me with an exhibition of dancing girls and music, which was very delectable. When the dancing and music were over, refreshments were served upon trays of solid gold sparkling with jewels. As it was growing late, and I felt afraid to remain longer, lest I should vex her, I made a motion of rising to leave. She immediately clapped her hands, and several slaves came forward, in obedience to her whispered commands, carrying trays heaped up with beautiful stuffs, and some silver articles of fine workmanship, which she pressed me to accept. After the usual salutations the old woman who first escorted me into the imperial presence conducted me out, and I was led from the room in precisely the same manner in which I had entered it, down to the foot of the staircase, where my own attendants awaited me.

—excerpted from "A Genoese Letter" in Eva March Tappan, ed., The World's Story: A History of the World in Story, Song, and Art, *Boston, 1914.*

A favorite subject was an idealized "civilized" landscape with pavilions, gardens, cypress trees and water.





Above: Water was a recurring element in embroideries in part because many pieces were intended to be used as towels and napkins. This exceptionally fine work in silk on linen from the mid-1800's has a very unusual design of wells in a landscape with trees. Right: The corner of this kerchief is a variant of the motif on the previous page. It was embroidered in very fine silk thread on muslin in the early 1800's.

The domestic embroideries, which began to survive in large numbers from the 18th century, are much less formal than the earlier ones, and they show best the imagination and individual taste of the women who created them. The Islamic prohibition on representing living things, though by no means universal, was often observed in Ottoman lands, and Marco Polo's beasts and birds had largely given way by this date to flowers.

One of the earliest patterns shows a flower—often it is a rose—with the leaf curled over it to make the pattern known in Turkish as *kambur* ("the hunchback"). It is not unlike the teardrop-like *boteh* pattern that characterizes paisleys and many Kashmir shawls. A line of these embroidered in a rather limited range of delicate colors is often found along the edge of a napkin, sash or towel.

Another favorite is a flower vase containing a posy, a symbol of good luck and happiness from China to England. In the Ottoman world, it was so much the emblem of a woman that it was often the form of her tombstone, just as the turban was for a man. There are literally thousands of variants, ranging from elaborate, professionally worked compositions enriched with gold and silver thread to simple but charming hyacinths, tulips, wild cyclamen, roses, carnations and even strawberries, each with its own popular symbolism and, occasionally, social connotations. This was the period when the "language of flowers" was also enjoying a great vogue in Europe, and posies were often designed to convey a message.

This is how the English writer Julia Pardoe described her experiences in Istanbul in the 1830's:

"We returned to the great centre saloon where the other ladies awaited us, surrounded by a crowd of slaves, one of whom carried upon a salver a pile of handkerchiefs, worked by the fair fingers of the two younger Hanoums [ladies], with gold thread and colored silks. This gift, which had been prepared for me, was accompanied by a thousand kindly comments. I was desired to examine one piece of needlework, and to remark that I carried away with me the heart of the donor. Upon another I was told that I should find a bouquet of flowers, and discover that they had presented me with the portrait which they should retain of me in their own memories."

Flowers were not always shown in vases. Sometimes they were arranged in geometric compositions at the ends of the napkins or sashes. Other times—on what are often professionally worked sheets, coverlets and towels—they form rich, deep borders of solid embroidery.

Less common than flowers, but also popular, were bowls of fruit, a symbol of abundance and hospitality particularly suitable to offer to a guest. Dishes of figs were a favorite; so was a melon with a knife stuck in it. Edgings of vine tendrils and fruit are found both along the Mediterranean coast and in the Greek islands—all grape-growing areas.

Another favorite subject, often so stylized as to be almost unrecognizable, was a variation of an ideal civilized landscape: Usually this meant a kiosk or the purely Turkish touches of pleasure tents, gardens, cypress trees and water.

Water motifs were particularly suitable for towels, and the occasional piece has views of fountains, aqueducts and even a well with a waterwheel. The Art Institute of Chicago has an unusual example on which three rows of silver fish swim against a seaweed-green background.

In the late 18th and early 19th centuries, muslin, rather than homespun linen, became popular for women's headscarves, and this was often worked with elaborately profiled borders and delicate garlands of flowers along the edges and in the corners. The patterns are sometimes copied from European textiles, especially French ones, which were beginning to be imported at the time.

Elaborately profiled borders and delicate garlands of flowers are sometimes inspired by European textiles.

The inscription in the corner of this finely embroidered square of silk and flat metal thread on muslin appears to read *hadiya li-sultan*—"a gift to a king"—indicating it was perhaps a present from a girl to her intended. It is not Topkapı-quality work, and a kerchief intended for the sultan would give his title formally. Below these words is *sana* (year) and a date: probably 1269 (1852/1853).

Calligraphy, while it occurs, is rare, and because many of the women were illiterate, it is often "pseudo-calligraphy" when it appears, resembling writing but actually meaningless. There are exceptions, where the embroideress copied a pious phrase, such as the *bismillâh* ("In the Name of God"), perhaps from a text or a tile panel; others may have shown a *tuğra*, or formal signature. For two types of work, however, the writing must have been drawn on the cloth by a scholar for the woman to embroider over: talismans to hang in the house, and protective shirts worn by the sick or by men going into battle. In these cases, verses from the Qur'an, prayers, one or more of the 99 names of God or selections from other texts were embroidered on plain linen, usually without decoration.

Embroidery, then, was a field for artistic expression. It was a potential source of income when times were hard. It was also one of the very few areas in which a girl could win the respect of her society and over which she had at least some control. Her work would be seen and admired (or criticized) at the hammam, at home when guests came to visit, and on major occasions when the family's finest embroideries would be put on display. Importantly, such displays gave potential mothers-in-law a sense of a young woman's skills and the quality of her trousseau.

A rather crude drawing dating from between 1645 and 1650 and entitled "Bride and Her Trousseau" shows a female figure and above her what looks like a washing line displaying a few small towels or napkins with flowery borders. This was indeed a common way of showing off işlemeler, which are difficult to display to advantage except when they are used, as was originally intended, as napkins and towels. The problem with this was pointed out in 1718 by Lady Mary Wortley Montagu while she was in Constantinople with her husband, the British ambassador. She wrote to a friend:

> I went to see the Sultana Hafiten…. She gave me a dinner of fifty dishes of meat, which (after their fashion) were placed on the table but one at a time, and was extremely tedious.
>
> But the piece of luxury which grieved my eyes was the tablecloth and napkins, as finely wrought as the finest handkerchiefs that ever came out of this country. You may be sure, they were entirely spoiled before dinner was over…. After dinner, water was brought in a golden basin, and towels of the same kind as the napkins, which I very unwillingly wiped my hands upon.

This no doubt explains the frequently indelible stains on so many antique işlemeler!

Visits to the hammam, the Turkish bath, were some of the few excursions permitted to Ottoman women, and they were enjoyed to the full. Not only was the visit an opportunity to meet other women and exchange news and gossip, but it was also the occasion for beauty treatments and a massage, and refreshments would often be brought along as well. Besides the cosmetics and other paraphernalia, a woman would be careful to choose some of her best embroidered towels in different sizes, as well as wrapping cloths (*bohçalar*) in which to carry her clothes and other possessions, since this was an occasion when she would be under scrutiny.

Textiles were mostly put to practical uses, but they also had more ceremonial ones. For example, it was common for the Qur'an to be wrapped in or covered by a particularly beautiful cloth, which both protected it and showed respect. Julia Pardoe described this: "Along a silken cord, on either side of the niche, were hung a number of napkins, richly worked and fringed with gold; and a large copy of the Koran was deposited beneath a handkerchief of old gauze, on a carved rosewood bracket."

Men's turbans, too, had importance, since they indicated rank and status conferred by the sultan. When not in use, they were kept covered by a special cloth, usually worked with a circular pattern, to keep the dust off and, again, to indicate respect. So symbolic were turbans that a man's tombstone often would be cut in the shape of a turban that indicated his social status.

This square, probably a woman's scarf, edged with stylized carnations delicately tied with bows of ribbon, clearly shows the influence of European textile imports into the Ottoman Empire. It was worked in silk and gold thread and tiny gold spangles on fine muslin in the first half of the 19th century.

For different reasons, cloths were used to keep mirrors covered when not in use. This was said to discourage vanity, but it also accorded with superstitions associated with mirrors. Mirror covers were generally long rectangles of light material, densely embroidered to hide the reflecting surface effectively.

Fine cloth was also used to hold an object or a gift, as was also the custom in Japan and other countries. What Charles White wrote in the 19th century would also have been true earlier:

> Muslin and cotton handkerchiefs…are employed less, perhaps, for the purposes to which such articles are applied in Europe, than for that of folding up money, linen, and other things. In the houses of the great men, there is always a *makrami başı*, whose principal duty is to take care of these and other similar articles. No object, great or small, is conveyed from one person to another, no present is made—even fees to a medical man—unless folded in a handkerchief, embroidered cloth or piece of gauze. The more rich the envelope, the higher the compliment to the receiver.

Traditional embroidery changed during the 19th century, when machine-made cloth began to replace hand-loomed, and in the same period a fatal disease wiped out much of the indigenous silk industry and led to the importation of silk thread from China. Although good enough in itself, it was different in type from that which had been produced in the Ottoman Empire. Later still, mercerized cotton, in a wide range of artificial colors, and often accompanied by giveaway pattern books, meant that the work tended to become more brilliant but coarser, and the repertory of embroidery motifs changed. Finally, from the 1920's onward, as Atatürk opened up the country, freed women from the harem and gave them education, jobs and a measure of independence, girls no longer had so much time for needlework, and—with new, exciting and productive opportunities available—they no longer saw it as their major creative outlet. ⊕

Caroline Stone divides her time between Cambridge and Seville. She and Paul Lunde have just produced a selection from Mas'udi's *Meadows of Gold* for the Penguin "Great Travellers" series; their translation of Ibn Fadlan and other Arab travelers to the North is scheduled to appear later in 2007.

Alexander Stone Lunde is studying economics and politics at Bath University, UK, and has been involved in several photographic projects. A selection of his work can be seen at www.phototropic.net and www.alamy.com.

Related articles from past issues can be found on our Web site, www.saudiaramcoworld.com. Click on "indexes," then on the cover of the issue indicated below.

Suzanis: J/A 03
Palestinian embroidery: J/F 91, M/A 97
North African embroidery: N/D 87
Swati embroidery: J/F 97
Lady Mary Wortley Montagu: J/A 80

HEALING SOUTH CENTRAL

Written by Pat McDonnell Twair   Photographed by Ben Tecumseh DeSoto

"You're only students."

That was the reaction from community leaders in 1992 when Rushdi Abdul Cader and six med-school friends proposed offering free medical services in South Central Los Angeles, then recently ravaged by riots.

What made the proposal even less plausible was that the seven, all members of the Muslim Students Association (MSA) at the University of California at Los Angeles (UCLA), had no money—and it would be years before they received their degrees.

Nonetheless, four years later, with the encouragement of their professors and Los Angeles City Councilwoman Rita Walters, the indefatigable idealists opened the first charity health clinic in the United States founded by Muslims. They named it UMMA, an acronym for "University Muslim Medical Association" and the Arabic word for "community."

According to co-founder Mansur Khan, MD, UMMA's roots actually go back to 1986. That was the year the MSA elected a president named Ali Galedary, an Iranian–American who had grown up in one of Los Angeles's Mexican–American working-class communities and who had volunteered in a gang-intervention program. "Up to then, the MSA had been strictly a social organization," Khan says. "Ali persuaded many of us to work as mentors and tutors to incarcerated teens in a Ventura facility. He told us, 'We have manpower and ability—let's do something serious.'"

Initially, the seven considered raising funds for a mobile health unit.

"Our objective was to make an impact on the well-being of the people of South Central as well as on our Muslim community," Khan continues. "We didn't see much social activism on the part of the first-generation Muslims, our parents, who were concerned about preserving their cultural identity and establishing Islamic religious and educational institutions."

"The 1992 riots were a catalyst," says Abdul Cader. A supportive professor helped the students take their idea to the Los Angeles City Council, where South Central Councilwoman Rita Walters told them, "Forget the trailer. I'll find you a building for a permanent clinic."

Los Angeles County is three times the size of the state of Rhode Island and a third the size of the Netherlands. It is home not only to billionaires in Bel-Air and Beverly Hills, but also to some 900,000 people in the South Central region who endure poverty and widespread homelessness.

The sky was still hazy from fires set during the riots following the trial of Rodney King's attackers when the UCLA students began driving to South Central to search for a building.

"We learned not to drive too slowly," Abdul Cader recalls. "We found out that gangbangers drive slowly into each other's territory when they're looking for trouble."

Councilwoman Walters announced she had located "the ideal site"—a boarded-up building on Florence Avenue, just two blocks from where the 1992 riots began.

"It was an eyesore," Abdul Cader recalls, "a derelict building with exposed wires and asbestos in the ceiling." Worse, there were toxic deposits left from when the site served as an auto-repair shop. But with Walters's support, the city cleaned up the toxins and another co-founder, Altaf Kazi, recruited his architect father, Mohammed Yusuf Kazi, to design the future clinic.

"I remember weeds and graffiti, drug paraphernalia and liquor bottles everywhere," says Kazi. "We took the structure down to its studs. My father drew up the blueprint for six exam rooms, a waiting room, a pharmacy and a large staff conference room."

Over the next three years, the students asked medical suppliers to donate examination tables, lamps, chairs and filing cabinets. While they waited for construction to end, they used their family garages and patios for storage.

Above right: **Outside the clinic that first opened its doors in 1996, staff and volunteers take a morning break in the California sunshine.** Right: **Steven Murphy, MD, medical director at UMMA, examines a young patient.** Opposite: **A tapestry embroidered with verses from the Qur'an hangs on the wall outside the examination rooms at the clinic.**

Dr. Murphy consults with a young mother.

The students also raised more than $1.3 million in grants, and in September 1996 UMMA opened its doors. Today, the clinic runs on an annual budget of $1.5 million that comes from fundraising, grants and state and county reimbursements for indigent care.

Abdul Cader, who was just beginning his internship as an emergency-room doctor when UMMA opened, served as the clinic's first medical director. Raziya Shaikh was its first manager. (She left to pursue a Ph.D in biology.)

"We turned a health hazard into a health center," Abdul Cader says proudly. "We accomplished all this because we had a window of time, before opening our practices and starting families, in which we could devote a lot of our energies to the clinic."

When the students distributed flyers announcing the opening of the clinic, their neighbors at first were skeptical. Some feared it was a government attempt to keep track of illegal immigrants. Others voiced doubts that a student operation would be permanent. "After you finish your research, you'll leave," they predicted.

"Within a few months, the people realized we weren't about 'diagnosing and adios-ing,'" says UMMA president and CEO Yasser Aman. "We take our role seriously: to serve one of the poorest communities in the country.

MAKING DOCTORS

"We don't just treat patients at UMMA," states co-founder Khaliq Siddiq, MD. "We actually make doctors here."

He was referring to UMMA's role as a teaching site for more than 200 medical students who have trained at the clinic in the past 10 years. This aspect of UMMA's work is overseen by Rumi Abdul Cader, MD, director of medical education at UMMA and an associate professor of medicine at UCLA's School of Medicine.

"The student program is the heart and soul of UMMA," says Abdul Cader, who notes that UMMA is one of the most popular community rotations for UCLA medical students.

"It's chiefly third-year medical students who come to UMMA," he explains. "UMMA is a teaching model which exposes medical students to the needs of the underserved. Hopefully, they develop cultural sensitivity in understanding the unique medical and social issues of the inner-city poor."

South Central has the highest rates in the country of premature births, foster children, child abuse and people without health insurance."

In that first year, UMMA treated a total of 800 patients. Today it serves about 6500 a year. And it's safe: The clinic and its grounds have been untouched by local gangs. One patient noted: "I feel like UMMA is a safe haven, a little bit of heaven in chaos."

Within one year, UMMA decided it didn't need a security guard. Neighbors assured the staff, "Don't worry, we take care of this clinic."

Aman explained that UMMA serves as a health "safety net" for some 15,000 patients who are uninsured, indigent or simply members of the "working poor." Some 70 percent of UMMA's patients are Latinos; fewer than five percent are Muslims.

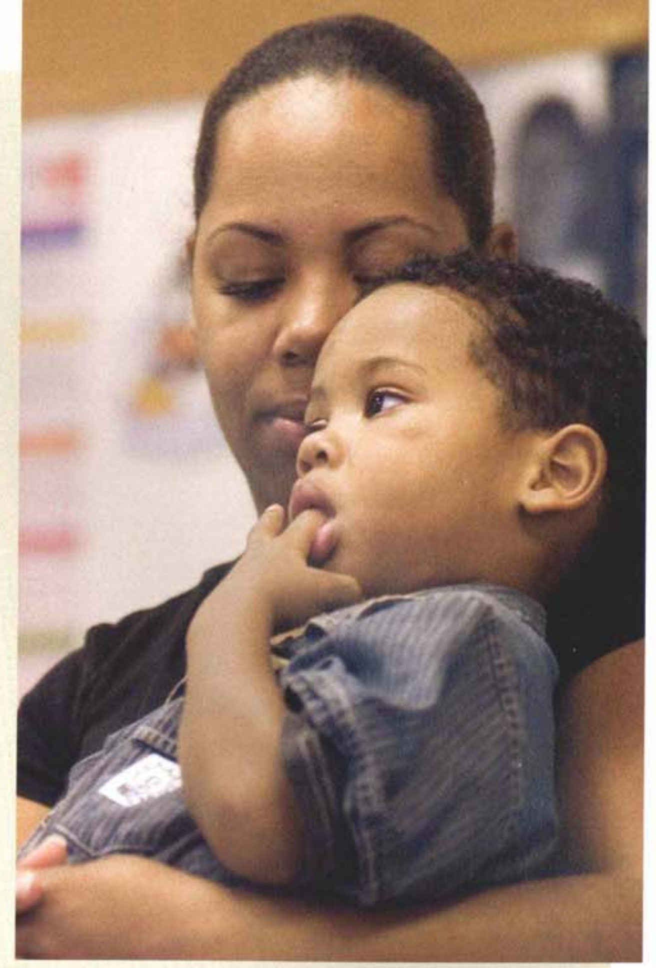
"The doctor-patient ratio in South Central is one physician for 29,000 people, while in Beverly Hills, it's five doctors to one person," Aman says. "The customary wait to be seen in the Los Angeles County health system, for patients with serious diseases, is six to nine months." In addition to UMMA's staff of 15, there is a pool of 20 volunteer physicians and a referral coordinator who counsels patients and sets up appointments with specialists, especially for diabetes and high blood pressure, which Aman calls "the silent killers we identify here." Overall, about one-third of the care given at UMMA is to children.

Pediatrician and co-founder Nisha Abdul Cader, Rushdi's wife, remembered how, during the first year, she examined a 12-year-old girl who was wasting away. "Other clinics had examined the child, but failed to diagnose her illness. I tested her for HIV, and she was positive. I learned she'd had a blood transfusion when she was born prematurely." She sent the child to Harbor-UCLA Medical Center, and today she's a student at the University of California at Davis.

Another UMMA success story deals with an uninsured father who struggled from paycheck to paycheck while suffering from an unknown ailment. His daughter had noticed the UMMA clinic sign and urged him to make a call there. He was diagnosed with ulcerative colitis, a potentially serious disease of the colon

"We turned a health hazard into a health center," Abdul Cader says proudly.

Right: The face of Noelle Levingston shows concern for her son Devin, 3, while they sit in the waiting room. Center: Pharmacy technician Rafael Gomez and volunteer doctor Naima Frewam, who was born in Libya, work in the pantry that stocks donated medicine. Lower: A certificate in the hall commemorates the national recognition UMMA received in 2006 in the US House of Representatives from Congresswoman Maxine Waters, who represents South Central. "If you want to see what Muslim Americans truly represent, go to UMMA Clinic," she said.



Left: Nidia Aparicio, 16, receives a booster shot as her family peers from the hallway door. The clinic is one of the few locations in the neighborhood where families can get the free immunizations required to attend public schools. Center: Through an annual breakfast served in the clinic's parking lot, Hoori Sadler, who manages her family's own medical group in Beverly Hills and is one of UMMA's top volunteers, has raised more than $700,000 for the clinic. "UMMA is in my blood. If you are a good Muslim, you give without being asked," she says. Lower: Eleanor Mateo runs the clinic's front desk.

that can increase the risk of cancer. Today, with proper care, his disease is under control.

On designated Saturdays, UMMA offers health fairs in its parking lot, conducting blood drives and offering diabetes and blood-pressure screening. Last February, it even held workshops on preparing tax returns.

Speaking in the US House of Representatives last July, Congresswoman Maxine Waters, who represents the South Central area, said, "If you want to see what Muslim Americans truly represent, go to UMMA Clinic, and you'll see it there. The students who founded UMMA were inspired by their Islamic faith, a faith which told them to help the neighbor, a faith which told them that if they saw something wrong, they must fix it."

In the presence of UMMA founders and supporters in the gallery, Waters went on to say that UMMA serves as a primary health-care source for more than 15,000 people in her congressional district, many of whom would otherwise have no access to primary health care services at all.

The clinic's success stories are spreading, and UMMA has received calls from Muslim groups in the California cities of San Bernardino and Sacramento, as well as from Detroit, Las Vegas, Houston and Raleigh, North Carolina. All are looking for guidance in establishing similar clinics; one is also starting up in Columbus, Ohio.

Other local social-service agencies respect UMMA's role. The executive director of the non-profit Esperanza Community Housing Corporation, Nancy Halpern, says, "I've witnessed how vital UMMA, this self-made gem of a health clinic, is as a provider of primary health care. It's also a responsible link to specialty health care for people who are largely uninsured," she adds.

Similarly, Jim Mangia, CEO of St. John's Well Child and Family Center, comments that "I don't know what would happen to thousands of patients if UMMA weren't here."

In 1999, UMMA received the Best Practices Award from the Department of Housing and Urban Development. In 2005, Kaiser Permanente bestowed on UMMA its National Community Service Sabbatical Award.

But far more than such awards, UMMA medical director Steven Murphy values the thanks of the clinic's patients. Many express their gratitude verbally, in Spanish or English; others, however, turn to the universal "thank you" of food: "They often bring us hot tamales, or a big pot of soup, and even fish caught off the Santa Monica pier," he says. ⊕

UMMA'S FOUNDERS—NOW

"I think people we asked for help reacted to our optimism and opened doors for us."
—NISHA ABDUL CADER

"In the early days of serving as the first manager, I pushed a button and minutes later five police cars were in the parking lot. I'd pushed the emergency alarm!"
—RAZIYA SHAIKH

"UMMA Clinic was an eye-opener for me. It made me more socially aware of the diverse cultures in Los Angeles."
—AISHA SIDDIQ

"We transformed a health hazard into a health center."
—RUSHDI ABDUL CADER

"UMMA's focus is not just on treating disease, but promoting health from infancy on up."
—ALTAF KAZI

"We don't just treat patients, we actually make doctors here."
—KHALIQ SIDDIQ

"UMMA is a safe haven in a high crime area."
—MANSUR KHAN, incoming chairman of the UMMA Clinic board of directors

PORTRAITS (7): SAMIR TWAIR

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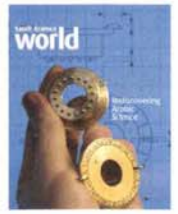
Classroom Guide

WRITTEN BY JULIE WEISS



For students: We hope this two-page guide will help sharpen your reading skills and deepen your understanding of this issue's articles.
For teachers: We encourage reproduction and adaptation of these ideas, freely and without further permission from *Saudi Aramco World*, by teachers at any level, whether working in a classroom or through home study.

—THE EDITORS

Analyzing Visual Images

This month's activities focus on the *edges* of photos—not only how photographers fill the "frame," but also how they make photos "end." It is part of how photographers and magazine designers decide what to include, what not to include. What are the effects of their choices?

First, look at the photograph on page 26 of the blue whale's flukes. The photo looks almost abstract, as if an artist made it up to create an interesting shape. But it's actually a representation of part of a whale. How does a photographer make such an image as compelling to look at as this one? Let's focus on the arrangement of the image in the frame. First, look at the foreground of the photo. The whale's flukes are there, breaking the plane of the water. Although this is a photo and not a movie, how does the image convey movement? Then look back into the photo. Behind the flukes are two horizontal lines. Notice that they break the picture into thirds. The front two-thirds shows water.

What is behind the water? What is behind that? What do these layers of background add to the photo? Finally, look at the right and left edges of the photo. Why do you think the photographer cropped the photo to have those edges? Imagine if she had pulled the lens back. How would the picture have been different?

Now look at the upper photo on page 39 in "Healing South Central." Consider its edges. What defines the left edge? The bottom or front edge? The right edge? Why do you think the photographer chose to frame the photo this way? Why do you think each element is included? Why does the "frame" take up so much of the photo's space? What is contained within the borders that have been created by the images on the edges of the photograph? Why do you think the people in the center of the photo are so small, compared to the overall size of the photograph? Imagine the photo with the people filling more of the frame. How would it be different? What would be lost?

Class Activities

Theme: Science

A large part of this issue of *Saudi Aramco World* focuses on Muslim contributions to science. In the activities that follow, you'll have a chance to think about what science is, and what things outside science shape it.

What is science? What assumptions do you hold about it?

For many of us, science is a subject you first study in school. As you get older, your studies tend to focus on one particular kind, or "field," of science, such as biology or chemistry or physics. What unites these different fields? Use a search engine to find definitions of the word *science*. Which definition or definitions seem most related to what you've studied and to what you think of as science? With a group, write your own one-paragraph definition of science. Your paragraph might include a dictionary-type definition, as well as examples of what is—and is *not*—science. Compare your paragraph with other groups' paragraphs. Revise your definition in light of new ideas you have received from your classmates.

With your definition in mind, now think about your *assumptions* about science. For example, maybe you assume that because science deals with facts, it is always right. Maybe you assume that science is a good way to learn how to solve big problems, like global warming or curing cancer. (Hint: Many assumptions seem so obvious you may not feel they are worth writing down. That's why they are assumptions!) Now, you might wonder why we should bother identifying assumptions about science. Here's why: Because those assumptions will affect how you understand and think about what you will be reading. If you know your assumptions, you will be clearer about which ideas you're reading make sense to you, and which you find challenging —or downright wrong—and why. With your group, then, list your assumptions about science. How many can you come up with? Keep your list handy as you work with the articles in this issue.

What factors affect scientific research?

Scientific research is affected by all kinds of things you might not think of. These include economics, politics and culture—three very abstract terms that deserve to be looked at to see what sense we can make of them.

Economics = money: Who pays for science? Who gives scientists money to do experiments, to read about things and to travel to look at things? It's fun to imagine "mad scientists" who never comb their hair sitting in basement laboratories surrounded by steaming concoctions on Bunsen burners. But real scientists have to think about things like: How will they pay the rent on their office-building lab space? And who's going to be sure they've got enough test tubes, telescopes and all the other equipment they need to do their experiments? (A lot of it is *very* expensive!)

Class Activities (cont.)

Read "Rediscovering Arabic Science." Highlight the parts that address the issue of funding scientific research. Who paid for scientific research at the various times described in the article? What do historians today say about that funding?

Scientific research is big business today, to the tune of billions of dollars a year. Who funds scientific research today? Do some research of your own to find out, and identify at least four different major sources of funding. Hints: Cast a wide net. Look at both public (government) and private (business) researchers and funders. And define scientific research broadly, including mathematics, medical research and research that leads to technological innovation. With your group, discuss how the different sources of funding for research might affect what research gets done and what doesn't. For example, ALS (also called "Lou Gehrig's Disease") has been called an "orphan disease," because not enough people suffer from it for pharmaceutical companies to invest large sums in research to find cures.

Now look back at the assumptions you listed about science. How does what you've just done relate to those assumptions? Do funding issues surprise you? Do they fit neatly with your assumptions about scientific research? Or do they contradict them? Write an informal response to the questions above. You'll return to them later.

Politics is more than elections: What does scientific research have to do with politics? Consider this quote from the article: "Islamic science ultimately went into an irreversible decline with the eclipse of Arab political and economic power, marked in the West by the fall of Granada in 1492." Find evidence in the article that supports the idea that the heyday of Arabic science coincided with the height of Islamic political power. Why do you think political power and scientific expansion are often connected? In addition to the examples in "Rediscovering Arabic Science," think about another example: the space race between the United States and the Soviet Union in the 1960's. What was the scientific research that the two superpowers were pursuing? Why was it only those two countries that pursued it, and not others? Jot down a few ideas about the relationship between political power and scientific research.

A key part of culture is language: In which language(s) are different kinds of information expressed? Think, for example, about traveling in the world today. In a majority of places, it's possible to get by speaking only English. That's because relatively recently people all over the world have begun to learn and use English. As a class, discuss why that's the case. What would it mean if a different language was spoken across most of the world? What about a world with no dominant or common language?

What is the language used in scientific research? If you have studied genus and species names (e.g., *Homo sapiens*), you know that they're in Latin. Hypothesize why that's the way it is. Now read "The Language" on page 5, which reports that for several centuries, the language of scientific research was Arabic. What does that fact reveal about scientific research, as well as political and economic power, at that time? Look back at what you wrote about how economics and politics relate to scientific research. Add culture to your analysis. Draft an outline of an essay that answers the question, "How do economics, politics and culture affect scientific research?" Exchange outlines with another student. Discuss each other's work, and advise each other about how to improve the outlines. Then write the essay.

Why is it important to know the history of science?

So far you have looked at what shapes scientific research. Now step back and think about what historians know about scientific research that was done in the past. One of the main points of "Rediscovering Arabic Science" is that many people who study the history of science don't know about the contributions that came from the Arab and Muslim worlds. How does something like that happen? Why does it matter? Find two reasons in the story. Then make a chart or timeline that shows some major Muslim contributions to the various fields of scientific research identified in the article. Add, in a different color, any later theories that were developed as a result of these scientific findings. Looking at your chart or timeline, and at the article, think about why it's worth telling the stories of the scientists whose stories have been lost, and the discoveries they made. Make a persuasive presentation advocating that this "lost chapter of history" be included in your school's curriculum. Make your presentation in whatever format you'd like.

Why is it important to know the geography of science?

On page 10, "Lines of Transmission" reports on how scientific ideas "migrated" from one area to another, and from one scientist to another. Read the article, which describes the transmission of science from Muslim lands to Europe as "an ongoing, fluid exchange." What does that mean? Write an explanation, including what characterizes a "fluid" exchange. Use examples from the article to support your point of view.

The next question: Why does it matter? Why might it be useful to know the information presented in "Lines of Transmission"? Think about what you've learned about what science is, and about the process of scientific development. What, if anything, does adding geography contribute to your knowledge? Either write an answer to the question, or hold a class debate about the value of knowing how scientific thinking migrated around the world. Then discuss how it is migrating around the world today. What are today's "lines of transmission"—and *where* are they?

What does the history of scientific research show us?

Look back at your list of assumptions about science. Do you have any that relate to the idea that science is always right, or that scientific thought develops in a straight line of progress from the "ignorant" past to the "enlightened" present? If so, what about scientific theories that turn out to be *wrong*? As you see in the article, science is at best a stop-and-go process riddled with errors! Find a part of "Rediscovering Arabic Science" that describes a scientist's mistakes. What caused him to make those mistakes? Find places that describe scientific findings that were lost of ignored. (Look in "Lines of Transmission" as well as the main article.) Add the mistakes and the ignored material to your timeline. What does discovering errors and omissions do to your assumptions about science? Write a final statement in which you reflect on what you thought about science when you began these activities, and how your ideas have, or have not, changed.

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Events&Exhibitions

This map of "Byzantium, Now Constantinople" is one of 546 views of cities from all over the world that appeared in *Civitates Orbis Terrarum*, an armchair traveler's delight whose six volumes were published in Cologne between 1572 and 1617, edited by Georg Braun and engraved mostly by Frans Hogenberg. The view is from the Asian side of the Bosporus westward up the Golden Horn; Topkapı Palace can be seen on the point of land where the Bosporus and Golden Horn meet, with the Süleymaniye Mosque beneath the word "Constantinopolis."

ORIENTAL INSTITUTE MUSEUM

European Cartographers and the Ottoman World 1500–1750: Maps From the Collection of O. J. Sopranos

This exhibition of maps, sea charts and atlases explores how mapmakers came to know and map the Ottoman world between the 15th and 18th centuries. It begins with the intellectual and geographical discoveries of the 15th century that undermined the medieval view of the cosmos, and illustrates how cartographers sought to produce and map a new geography of the world, one that reconciled classical ideas and theories with the information collected and brought back by travelers and voyagers. To illustrate these developments, the exhibit is organized around such themes as the rediscovery of Ptolemy's *Geographia* and its impact on geographic thought and mapping practices; the practical tradition of sea charting that developed in the Mediterranean; the new cartographies of Giacomo Gastaldi and Abraham Ortelius, who sought to hold up a mirror to the known world; the production of Ottoman geographies; and the ways in which enlightened French cartography affected the relationship between the Ottoman Empire and the rest of Europe. The exhibits include manuscript portolan charts and atlases, the earliest printed maps of the Ottoman Empire, an Ottoman sea atlas, bird's-eye views of cities, a rare printed Ottoman atlas from the early 19th century, decorative regional maps, a sea chart described as among the finest examples of 18th-century Dutch map art, and sketches, memoirs and reports from travelers whose observations and descriptions of the Ottoman world enabled cartographers to update their maps. The exhibition demonstrates the power of maps to reflect and shape geographical knowledge of that part of the world we know today as the Middle East. Oriental Institute Museum, **Chicago**, November 2 through March 2.

<<< Last Call

Cosmophilia: Islamic Art From the David Collection, Copenhagen explores for the first time the roles played by the lavish use of ornamentation, one of the most characteristic and attractive features of Islamic art. More than 120 of the finest pieces from the unparalleled David Collection are organized visually in five sections—figures, writing, geometry, vegetation and arabesque, and hybrids—that together comprise the visual arts of the Islamic lands. The objects range in medium from jewelry to carpets, in date from the seventh to the 19th century, and geographically from western Europe to East Asia; most have never before been displayed in the United States. The exhibition—one of the most comprehensive since Munich in 1910 and London in 1976—examines the various characteristics of Islamic arts: color, repetition, symmetry, direction, juxtaposition, layering, framing, transferability, abstraction and ambiguity. Catalogue $50. Smart Museum of Art, University of **Chicago**, through May 20.

A Light Unto the Nations. Eight Muslim and Jewish photographers join to use their craft to oppose ignorance and intolerance, and exhibit the result at the Contact Photography Festival. Lennox Contemporary, **Toronto**, through May 20.

Glass, Gilding and Grand Design: Art of Sasanian Iran. The Sasanian Dynasty ruled Persia for 400 years, from the second century until the Arab conquest in 642. Its founder, Ardashir, overthrew the Parthian Empire and built one of the great powers of antiquity. The Sasanians' rivals were Rome and Byzantium in the West; in the East they were in touch with the mobile kingdoms of Central Asia and maintained relations with China. Sasanid art is dominated by the image of the glorious ruler, carved into mountainsides, engraved on precious stones, depicted in the bottom of golden drinking cups and placed at the center of banqueting, hunting and ceremonial scenes as guarantor of the unity of the vast empire. The Sasanian court was one of legendary splendor, and it supported a remarkable flowering of the decorative arts. The exhibition presents about 70 works of art—silver-gilt plates, gold cups, fine glass, precious textiles, cameos and other carved stones, arms and coins—that testify to the diversity and iconographic variety of a culture where Hellenistic influences combined with older Iranian traditions. Asia Society, **New York**, through May 20.

Stories from the Silk Road takes children on a picture-book journey on the Silk Road to experience the cultures, landscapes and peoples of different lands. This exhibition features original illustrations from books about the people who traveled the Silk Road, including Muslim scholar Ibn Battuta, Genghis Khan and Marco Polo. Illustrations from Chinese and Indian folktales are also be on view. Artists included are Helen Cann, Demi (Charlotte Dumaresq Hunt), Yumi Heo, James Rumford and Peter Sis. Art Institute of **Chicago**, through May 28.

Adnan Charara: JUXTAPOSED features new artwork that explores the challenges of immigrating to the United States and the process of becoming American. Drawing on the firsthand experiences of an immigrant artist, this work reflects the ways in which people retain their traditions while assimilating to a new culture, and the way these traditions contribute to a broader American identity. These themes speak not only to the Arab-American experience, but also to the experiences of most immigrant communities in America. National Arab American Museum, **Dearborn, Michigan**, through May 31.

The Emperor's Terrapin was carved around 1600 and found on the grounds of the fort at Allahabad in northern India in 1803. It is associated with Crown Prince Selim, later to be the Emperor Jahangir, son of the great Mughal emperor Akbar. "Turtles are marvelous sculptural pieces," said Sir David Attenborough, "and as such clearly inspired the Mughal artist working with a spectacular jade boulder." Cartwright Hall, **Bradford [UK]**, through June 3.

Lady Mary Wortley Montagu was one of the most influential women and one of the most renowned writers of the 18th century, and this first major exhibition of paintings, prints and letters celebrates the life of a woman who was ahead of her time. Lady Mary was a key figure in the introduction of the smallpox inoculation in England, a practice she discovered in use while living in Turkey and adopted for her own children. Her letters and diaries from that period, intelligent, witty and openminded, are an excellent and unconventional source of information about the Ottoman Empire of the time. The exhibition uses her writings to explore the different aspects of her life. Graves Art Gallery, **Sheffield [UK]**, through June 3.

Treasures from Olana: Landscapes by Frederic Edwin Church features 18 of the artist's own paintings that he displayed in his carefully devised interiors at Olana. The majority are landscape oil sketches, which illustrate the artist's favorite domestic landscapes and his journeys not only to the Middle East, but also to South America and Europe. During a period of debate regarding the artistic merit of an oil sketch versus a finished painting, Church boldly exhibited these *plein-air* oil sketches as finished works of art alongside his precisely rendered "Great Pictures"—a testament to his belief in the quality of these smaller works. This is the first time they have been displayed together outside Olana. **Princeton [New Jersey]** University Art Museum, through June 10.

<<< Ongoing

Uncomfortable Truths: The Shadow of Slave Trading on Contemporary Art and Design displays new and specially commissioned work to address the ways in which the legacy of slavery informs contemporary art and design. The exhibition commemorates the bicentenary of Britain's abolition of the transatlantic slave trade, and features the work of artists from the United States (Michael Paul Britto and Fred Wilson), Britain (Anissa-Jane, Lubaina Himid, Keith Piper and Yinka Shonibare), Africa (El Anatsui, Tapfuma Gutsa, Romuald Hazoumé and Julien Sinzogan) and Europe (Christine Meisner). Victoria & Albert Museum, **London**, through June 17.

Europe and the Islamic World: Prints, Drawings, and Books. In conjunction with the special exhibition *Venice and the Islamic World, 828–1797*, a selection of works on paper drawn from the museum's permanent collection explores the related theme of Europe's fascination with the peoples, costume, design and customs of Muslim lands. From Albrecht Dürer's 15th-century engraving of a Turkish family to the sketches drawn by Eugène Delacroix during his visit to Morocco in 1832, the images produced by artists fed the public's curiosity about a culture they both feared and admired—and often imitated. Visual records of diplomatic missions as well as documents of the influence of Islamic traditions on European dress and architecture are featured. Metropolitan Museum of Art, **New York**, through June 24.

Art of the Islamic World: Unity and Diversity. The first installment of this two-part display explores the Islamic world's role as intermediary between East and West, highlighting objects from Ottoman Turkey and Safavid Persia. Art Institute of **Chicago**, through June 30.

Egyptian Antiquities From the Louvre: Journey to the Afterlife includes stone and bronze sculpture, illustrated manuscripts, painted chests and mummy cases, *ushabti* figures, reliefs, jewelry, ceramics and fine wood carvings. All of the more than 200 objects illuminate the ancient Egyptians' concern with the afterlife, for which mortal existence was only a preparation, and of whose delights it was a mere shadow. A life lived morally and in accord with the commandments would allow a soul to pass through the final gate from the underworld into the paradise of the Field of Reeds. Art Gallery of South **Australia, Adelaide**, through July 1; Art Gallery of Western **Australia, Perth**, July 21 through October 28.

Egypt: 3000 Years of Decorative Art. Musée des Arts Décoratifs, **Bordeaux, France**, through July 2.

RED explores the use and meaning of this potent color in textiles across time and place. From the pre-Columbian high Andes to the 21st century streets of New York, red textiles are a compelling symbol, representing passion, power, status and human emotion itself. The difficulty of achieving this highly evocative color in textiles heightened the importance and allure of red cloth, which became a prestige commodity in many societies. The earliest textile in the exhibition is more than 2000 years old; others include an ancient Peruvian tunic border fragment, a Turkish velvet panel, a Chinese rank badge, a Navajo rug, a couture ball gown and an AIDS Awareness ribbon. Textile Museum, **Washington, D.C.**, through July 8.

Venice and the Islamic World, 828–1797 explores one of the most important and distinctive facets of Venetian art history: the exchange of art objects and the interchange of artistic ideas between the great maritime city and her Islamic neighbors in the eastern Mediterranean. Glass, textiles, carpets, arms and armor, ceramics, sculpture, metalwork, furniture, paintings, drawings, prints, book bindings and manuscripts—nearly 200 works of art—tell the story of Islamic contributions to the arts of Venice during her heyday, from the medieval to the baroque eras. (The exhibition's bookend dates are 828, the year two Venetian merchants stole St. Mark's body from Muslim Alexandria and brought it to their native city, and 1797, when Venice fell to Napoleon Bonaparte.) The exhibition opens with a gallery dedicated to the Venetian experience of traveling to and living in Islamic lands: Trade, travel and cultural and diplomatic relations were the most important vehicles for the exchange of artistic ideas. The main body of the exhibition unfolds chronologically, with the earliest Islamic objects to arrive in Venice, often for use in Venetian ecclesiastical settings. Also important were medieval Islamic scientific instruments and manuscripts, far more advanced than anything then available in Europe. The heart of the exhibition is formed of objects from the 15th and 16th centuries, when Venetian interest in the Islamic world peaked, with painter Gentile Bellini's visit to the court of Sultan Mehmet II as a point of departure. Metropolitan Museum of Art, **New York**, through July 8.

Butabu: Adobe Architecture of West Africa: Photographs by James Morris presents 50 large-scale images of structures from monumental mosques to family homes. For centuries, complex adobe structures have been built in the Sahel region of western Africa. Made only of earth mixed with water, these buildings display a remarkable diversity of form. Morris, a British photographer whose work centers on the built environment, spent several months traveling to remote villages and desert communities to photograph these organically shaped, labor-intensive adobe structures, creating both a typological record of regional adobe construction as well as an artist's rendering of West African architecture that reflects the sensuous, surreal and sculptural quality of these distinctive buildings. Several ambitious religious buildings seem to push the physical limits of mud architecture. More humble structures, such as private homes or neighborhood mosques and churches, are highly expressive and stylish, and are often intricately decorated. These African adobe buildings share many of the qualities now much admired in the West: sustainability, sculptural form and the participation of the community in conception, fabrication and preservation. ⓘ (310) 825-4361, www.fowler.ucla.edu. UCLA Fowler Museum of Cultural History, **Los Angeles**, through July 15.

Treasures of Ancient Egypt presents more than 200 artifacts, from statuary and relief to coffins, funerary art and everyday domestic objects, to shed light on the life of the ancient Egyptians. Art Gallery of **Nova Scotia, Halifax**, through August 19.

Architectural Textiles: Tent Bands of Central Asia highlights a unique and fundamental weaving: the tent band. The trellis tent has made nomadic life possible across Central Asia for at least 1500 years. An important component of its construction is a woven tent band, which girdles and braces the lower part of the wooden roof struts against the heavy load of felts and the force of strong winds. Beyond that function, tent bands are often elaborately decorated. The exhibition features approximately 40 tent bands made by different Central Asian ethnic groups, including Turkmen, Kyrgyz, Uzbek and Kazakh, and representing a wide range of structures, colors, designs and materials. Period photographs of nomadic life and weaving provide context and an educational gallery teaches visitors how to "read" a tent band. Textile Museum, **Washington, D.C.**, through August 19.

Architecture of the Veil: An Installation by Samta Benyahia—the first US museum exhibition by the Algerian artist—takes its theme from the *moucharabieh*, the openwork screens used in Mediterranean Islamic architecture to cover windows and balconies, allowing those inside—typically women—to view the outside world without being seen. The installation provides a beautiful and dynamic exploration of gender as well as the dialectic between interior and exterior, light and shadow, concealment and revelation, and private versus public space. Fowler Museum at UCLA, **Los Angeles**, through September 2.

The Jazira: A Cultural Landscape Between the Euphrates and the Tigris presents the art and culture of the petty princes of the region—the *jazira*, or "island"—in the 12th and 13th centuries. The medieval dynasties of the Zanjids, Artuqids and Ayyubids favored a courtly lifestyle that manifested itself in opulent libraries and artistic production, and featured extensive figurative representation in objects of art and architectural design. Artisans were encouraged to study the symbols of the illustrious past, including astrological symbols, and to re-use them for the glorification of their princely patrons. The exhibition's 70 objects include masterpieces, never published or barely remembered, in their historical context; they exemplify one little-known but particularly interesting epoch in Islamic culture. Pergamonmuseum, Museum für Islamische Kunst, **Berlin**, through September 2.

Masters of the Plains: Ancient Nomads of Russia and Canada examines two of the world's great nomadic cultures side by side for the first time, providing a unique look at the bison hunters of the Great Plains of North America and the livestock herders of the Eurasian steppes. More than 400 artifacts from Canada and Russia permit exploration of food preparation, sacred ceremonies, art, trade, housing design, modes of travel and warfare in the two cultures, which each took shape some 5000 years ago and lasted into recent times—a longevity that compares favorably with history's greatest civilizations. Canadian Museum of Civilization, **Gatineau, Quebec**, through September 3.

Blue & White: Objects in Blue & White from Egypt to China. Cobalt blue has been used to decorate ceramics since the 10th century. The earliest examples of the technique come from Egypt; it then spread to Persia and onward. From the 14th century, it became the well known blue-and-white Chinese porcelain, which in turn influenced ceramics in Persia, Turkey and eventually Europe. While at first it was Persian and Arab merchants who dealt in cobalt blue ceramics, which were much in demand in the Islamic world, Europeans—especially the Portuguese and Dutch—took over the Asian trade in the 16th century. Chinese porcelain manufactories supplied, on their customers' request, decorations and shapes in European styles. In Europe and the Islamic world, the demand for blue-and-white ceramics remained strong for centuries, and was met not only by imports but also by domestic ceramic producers. China's neighbors, Vietnam, Korea and Japan, were also big importers of Chinese porcelain until they built their own factories and became competitors. For centuries, "blue-and-white" remained a symbol of intercultural relations. Museum of Applied Arts / Contemporary Art, **Vienna**, through September 9.

Pharaohs, Queens and Goddesses is presented in tandem with *The Dinner Party* by Judy Chicago and dedicated to powerful female pharaohs, queens and goddesses of Egyptian history. The central object of the exhibition is a granite head of Hatshepsut, the fifth pharaoh of the Eighteenth Dynasty (1539–1292 BC) and one of the 39 women represented with a plate at *The Dinner Party*. Hatshepsut is featured alongside other women and goddesses from Egyptian history, including queens Cleopatra, Nefertiti, and Tiye and the goddesses Sakhmet, Mut, Neith, Wadjet, Bastet, Satis, and Nephthys—many of whom appear on *The Dinner Party*'s tiles. **Brooklyn** Museum, **New York**, through September 16.

Persia: 30 Centuries of Arts and Culture presents nearly 200 works from Persia's antiquity to the end of the Qajar Dynasty in 1925. The exhibition begins with the Achaemenids, who built roads, canals, splendid palaces and temples adorned with sculptures and bas-reliefs. At the edges of their empire, nomadic peoples also left traces: Nomads from the Scythian Empire built monumental burial mounds. First excavated in the time of Peter the Great, these *kurgans* yielded spectacular gold objects. In the second half of the fourth century BC, the Achaemenids' weakened state was conquered by Alexander the Great, and Greek influence is clearly visible in the great cultures of the Parthians and the Sassanids. The latter excelled at making elaborately worked silver objects, often decorated with hunting scenes. With the advent of Islam, the vocabulary of art changed. The exhibition displays bronzes, such as a remarkable incense burner in the shape of a cock, and earthenware, including a suite of 22 frieze tiles from the 13th-century mausoleum of Pir Husayn. Persian miniatures flowered in the 15th and 16th centuries, and nearly 40 miniatures and book manuscripts are included in the exhibition. Two rooms are devoted to other Persian art between the 15th and the 18th centuries, including ceramic dishes—some of whose forms and cobalt decoration show Chinese influence—and glass, much of it produced in Shiraz. Among costly and fragile Persian textiles are two striking 16th-century fragments, both showing a prince at a banquet in a blossoming garden. Persian envoys often took valuable fabrics such as these with them as diplomatic gifts. The exhibition ends with a survey of the art of the Qajars, marked by great splendor, luxury and opulence. Hermitage **Amsterdam**, through September 16.

Tutankhamun and the Golden Age of the Pharaohs includes 130 works from the Egyptian National Museum and presents a selection of 50 spectacular objects excavated from the tomb of Tutankhamun, including one of the canopic coffinettes, inlaid with gold and precious stones, that contained his mummified internal organs. Additional pieces in the exhibition derive from the tombs of royalty and high officials of the 18th Dynasty, primarily from the Valley of the Kings. These additional works place the unique finds from the tomb of Tutankhamun into context and illustrate the wealth and development of Egyptian burial practice during the New Kingdom. The exhibition, more than twice the size of the 1979 "King Tut" exhibition, marks the first time treasures of Tutankhamun have visited America in 26 years. Franklin Institute, **Philadelphia**, through September 30.

Gaza at the Crossroads of Civilizations presents 121 objects, most excavated by joint Palestinian–French rescue digs since 1994, that underline the city's archeological importance and testify to the great variety of national and ethnic groups that have lived here. The finds include Egyptian, Hellenistic and Roman pottery, Byzantine mosaics, Egyptian alabaster, a Greek helmet and Ottoman architectural fragments, here supplemented by photographs of the sites where they were found. Musée d'Art et d'Histoire, **Geneva**, through October 7.

Perpetual Glory: Medieval Islamic Ceramics from the Harvey B. Plotnick Collection presents about 100 treasures from what is generally regarded as the finest private collection of early Islamic ceramics in the world. They range in date from the early Abbasid caliphate in Iraq (9th–10th century) and the Mongol Ilkhanid dynasty in Iran (mid-13th–mid-14th century) to the Timurid dynasty in eastern central Asia (14th–15th century).The dramatic development of ceramics in the medieval Islamic period amounted to an industrial revolution. Glazed pottery—white wares painted in cobalt blue, luxurious lusterware and prized splashware—was produced in larger quantities and varieties than ever before and was traded widely along the Silk Road. The exhibition closely examines the most important types of ceramics produced in Iraq and Iran during this time—lusterware, slip-painted ceramics, underglaze-painted wares, and overglaze-painted wares most commonly known as *mina'i*—and features these objects with a number of contextual examples from Egypt, Syria, Afghanistan and Central Asia. The extraordinary achievements of Islamic pottery are explored in depth in the example of lusterware, which was produced through an exacting process involving the application of metallic solutions—usually copper and silver oxides—and multiple firings. Lusterware was first developed in Iraq in the ninth century and was imitated and prized by the Fatimid rulers in Egypt starting in the mid-10th century before spreading to Syria, Anatolia and ultimately Iran, where it reached its technical and artistic peak. Art Institute of **Chicago**, through October 28.

Amarna: Ancient Egypt's Place in the Sun offers a rare look at the unique royal center of Amarna, the ancient city of Akhetaten, which grew, flourished and vanished in hardly more than a generation's time. The exhibition features more than 100 artifacts, including statuary of gods, goddesses and royalty, monumental reliefs, golden jewelry, personal items of the royal family and artists' materials from the royal workshops. University of **Pennsylvania** Museum of Archaeology and Anthropology, **Philadelphia**, through October.

Egypt's Sunken Treasures presents a spectacular collection of artifacts recovered from the seabed off the coast of Alexandria and in Aboukir Bay. Lost from view for more than 1000 years, they were brought to light by an ongoing series of expeditions first launched in 1992 by the European Institute of Underwater Archaeology, headed by Franck Goddio. Thanks to these excavations, important parts of a lost world have resurfaced, among them the ancient city of Thonis-Heracleion, the eastern reaches of Canopus, the sunken part of the Great Port of Alexandria and the city's legendary royal quarter. The finds shed new light on the history of those cities and of Egypt as a whole over a period of almost 1500 years, from the last pharaonic dynasties to the dawn of the Islamic era. In Roman times the port city was notorious for its dissolution and debauchery; in the Christian era an important monastery was erected on the site of the ancient temples. Canopus was claimed by the sea at some point in the eighth century, and there are no finds that can be dated any later than the eighth-century Umayyad coins recovered from the seabed at the site of the vanished city. Art and Exhibition Hall, **Bonn, Germany**, through January 27.

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This 33-cm. silver plate, made in Portugal in the 15th century, shows a three-masted trading vessel.

MUSEU NACIONAL DE ARTE ANTIGUA, LISBON

Encompassing the Globe: Portugal and the World in the 16th and 17th Centuries brings together approximately 300 extraordinary objects reflecting the unprecedented cross-cultural dialogue that followed the establishment of Portugal's world trading network in the 16th and 17th centuries. Portugal was the first European nation to build an extensive commercial empire, which soon reached to Africa, India, China, Southeast Asia, Japan and Brazil. Portuguese contact with these regions, which had been virtually unknown to Europeans, led to the creation of highly original works of art, some intended for export and others for domestic consumption in their countries of origin. Initially displayed in princely "wonder cabinets"—the ancestors of the modern museum—and now scattered throughout the world, the paintings, sculptures, manuscripts, maps, early books and other objects assembled here provide a rich image of a "new world" during its formation. Sackler Gallery, **Washington, D.C.**, June 23 through September 16.

<<<May

Daily Life Ornamented: The Medieval Persian City of Rayy examines the distinctive artistic traditions of this great Islamic city, predecessor of modern Tehran. Rayy was a center of politics and sciences between the ninth and 13th centuries, renowned for its glazed ceramics and its prominent position on the Silk Roads. While documents reveal the personalities and events in the history of Rayy, patterns of its society and culture are brought to life through archeological materials. The city's unique ceramic heritage is revealed through excavations of the 1930's. The exhibition approaches more than 50 objects from this collection as an archeologist would, investigating both ceramic innovations and traditions. The theme of ornamentation acts as a guide toward understanding the city of Rayy as both the source and consumer of beauty in everyday life—illuminating the lifestyles, resources and values of its people. Catalog. Oriental Institute Museum, **Chicago**, May 15 through October 14.

Battle of the Bands: New England *Mehterhane* vs. Connecticut Valley Field Music. Ottoman Janissary bands, or *mehterhane*, had a significant impact on western music for many centuries. The first European marching bands combined several different-sized drums, brass percussion and winds in direct imitation of the Janissary bands. The traditional American fife and drum band is an example of Turkish *mehterhane* influence in the New World in the 18th and 19th centuries. Having an American fife and drum band in this "battle" brings different generations of marching bands onto the same stage in a competition that mirrors the centuries of competition between Ottoman and European civilizations. 8 p.m., $20. Kresge Auditorium, **Massachusetts** Institute of Technology, **Cambridge**, May 18.

Indigo: A Blue to Dye For spans a long, rich history, from the oldest known indigo recipe, written in cuneiform on a Babylonian clay tablet, through linen and wool burial cloths dyed in Roman Egypt, to Coptic textiles, to a portrait of Qajar Sultan Fat'h 'Ali Shah in an indigo-dyed robe and indigo-stained beard, to domestic textiles and clothing dyed in India and exported to Europe by the East India Company in the 16th through 18th centuries. More recent history is traced through the rediscovery of indigo discharge techniques by William Morris, the manufacture of synthetic indigo in the later 19th century and the growing popularity of denim jeans. The exhibition also features the work of present-day craftspeople in the UK, Japan, India, Bangladesh, Indonesia, West Africa and South America, which illustrate indigo's survival and adaptation to contemporary fashion, and an indigo painting by Palestinian artist Nasser Soumi. The portion of the exhibition on the process of indigo dyeing includes dye blocks and balls, botanical drawings and videos of cloth being dyed in different parts of the world. **Plymouth [UK]** City Museum and Art Gallery, May 19 through September 1.

Persian Visions: Contemporary Photography From Iran presents more than 80 images that provide a revealing view of Iranian life and experience. The 20 artists featured are among Iran's most celebrated and include Esmail Abbasi (references to Persian literature), Bahman Jalali, Shariyar Tavakoli (family histories), Mehran Mohajer, Shoukoufeh Alidousti (self-portraits and family photographs) and Ebrahim Kahdem-Bayatvin. Some have lived abroad and returned to view their homeland from a changed perspective. Anti-exotic and specific, these images make up the first survey of contemporary Iranian photography to be presented in the United States. Pacific Asia Museum, **Pasadena, California**, May 21 through September 9; University of **Michigan** Museum of Art, **Ann Arbor**, October 6 through January 8.

Tenth International Congress on the History and Archaeology of Jordan will focus on the many peoples and cultures that crossed the Jordan River from the earliest times to the present, and on the conservation of Jordan's heritage. George Washington University, **Washington, D.C.**, May 23–28.

Art of Being Tuareg: Sahara Nomads in a Modern World. The elegance and beauty of the Tuareg peoples—their dress and ornament, their large white riding camels, their refined song, speech and dance—have all been rhapsodically described by travelers in Niger, Mali and Nigeria. This exhibition explores the history and culture of the Tuareg through their silver jewelry, clothing, leather purses, bags and saddles, and other highly decorated items. Cantor Center, Stanford University, **Palo Alto, California**, May 30 through September 2.

<<<June

The Emperor's Terrapin was carved around 1600 and found on the grounds of the fort at Allahabad in northern India in 1803. It is associated with Crown Prince Selim, later to be the Emperor Jahangir, son of the great Mughal emperor Akbar. "Turtles are marvelous sculptural pieces," said Sir David Attenborough, "and as such clearly inspired the Mughal artist working with a spectacular jade boulder." Horniman Museum, **London**, June 6 through July 29.

Greeks on the Black Sea: Ancient Art from the Hermitage. At the end of the seventh century BC, Greek city-states created settlements in the northern Black Sea region, which quickly became wealthy through trade with such indigenous tribes as the Scythians. Artisans working there produced objects that linked Greek artistic traditions with those of the cultures of the Eurasian steppes. In collaboration with the State Hermitage Museum in Saint Petersburg, this exhibition features approximately 175 objects of the Greek and Roman periods that demonstrate the opulence and high aesthetic quality of these unique works of art. Getty Villa, **Pacific Palisades, California**, June 14 through September 3.

Islam: Treasures From the Collection of Nasser D. Khalili presents 300 objects that provide a comprehensive survey of the arts of Islam from the eighth to the late 19th century. Art Gallery of **New South Wales, Sydney**, June 22 through September 23.

<<<July

Edge of Arabia: Art and Identity in the Land of the Prophet explores the individual expression of values and beliefs in a climate of change, and features works by 10 leading artists including Ahmed Mater al-Ziad Aseeri, Abdulaziz Ashour, Manal Al-Dowayan, Yosef Jafa, Khalid Yosseff, Ayman Yosry Daydban and Lulwah Al-Homoud. SOAS Brunei Gallery, **London**, July 11 through September 22.

From Soho Road to the Punjab documents the contribution of *bhangra* and its cultural relevance in Britain today. SOAS Brunei Gallery, **London**, July 11 through September 22.

<<<September

Wondrous Words: The Poetic Mastery of Jalal al-Din Rumi is a conference organized by the Iran Heritage Foundation and the British Museum to mark the 800th anniversary of Rumi's birth. ⓘ +44-20-7493-4766, info@iranheritage.org, www.iranheritage.com/rumiconference. **London**, September 20–22.

Impressed by Light: Photographs From Paper Negatives, 1840–1860 demonstrates that calotypes—photographs from paper negatives—flourished rather than failed in Britain after the introduction of glass negatives in 1851. Artists who used the paper negative process did so because they preferred its esthetic qualities, because it offered practical advantages for travel photography in hot climates, or because it helped to distinguish gentleman-amateur photographers from tradesmen. The exhibition is divided into four sections: The Rise of the Calotype, 1839–1851; The Calotype in Great Britain; British Calotypists Abroad; and The Calotype in British India. Metropolitan Museum of Art, **New York**, September 25 through December 31.

<<<October

Gifts for the Gods: Images from Egyptian Temples. Throughout their long history, the ancient Egyptians used copper, bronze, gold and silver to create lustrous, graceful statuary that, most characteristically, stood at the crux of their interactions with their gods, from ritual dramas that took place within the temples and chapels that dotted the landscape everywhere, to the festival processions through the towns and countryside that were thronged by believers. This is the first exhibition to focus on the art and significance of Egyptian metal statuary; it presents a new understanding of this type of statuary, its influences and its meaning. On view from domestic and international collections are some 70 superb statues and statuettes created in precious metals and copper alloys over more than two millennia, including several of the extremely rare inlaid and decorated large bronzes, between 60 and 110 centimeters tall, from the Third Intermediate Period (1070–664 BC), which represents the apogee of Egyptian metalwork. Catalogue. Metropolitan Museum of Art, **New York**, October 16 through February 18.

The Phoenicians and the Mediterranean presents aspects of the culture of these famed navigators and merchants, beginning with their origins around the city-states of Byblos, Sidon and Tyre. Known primarily for their diffusion of the alphabet and their remarkable sculpture, the Phoenicians were also creators of household objects and furnishings of great refinement. The exhibition deals with Phoenicians' writing—on coins, seals, clay tablets and stone stelae—their religion—represented by stone and metal statues of their pantheon and commemorative plaques—their commerce—responsible for the pan-Mediterranean diffusion of purple cloth and cedar wood—and their craftsmanship in glass, pottery, ivory and precious metals. Institut du Monde Arabe, **Paris**, October 16 through March 30.

The Legacy of Timbuktu: Wonders of the Written Word centers on manuscripts from the Mamma Haidara Memorial Library in Timbuktu, examples of a local book-production industry that was one aspect of the city's role as a celebrated center of learning that attracted scholars, teachers and students from many countries and cultures of the Muslim world. The city's role as a caravan crossroads complemented its book industry, facilitating the importation of books as well as students. Teaching, learning, researching, writing, transcribing, adorning, binding and trading in books connected Timbuktu to the global Islamic knowledge industry and culminated in a complex, viable socio-economic model. International Museum of Muslim Cultures, **Jackson, Mississippi**, November and December.

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The Saudi Aramco Exhibit relates the heritage of Arab-Islamic scientists and scholars of the past to the technology of today's petroleum exploration, production and transportation, set against the background of the natural history of Saudi Arabia. **Dhahran, Saudi Arabia.**

Information is correct at press time, but please reconfirm dates and times before traveling. Most institutions listed have further information available on the World Wide Web, and our Web site, saudiaramcoworld.com, contains more extensive listings. Readers are welcome to submit information for possible inclusion in this listing.

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