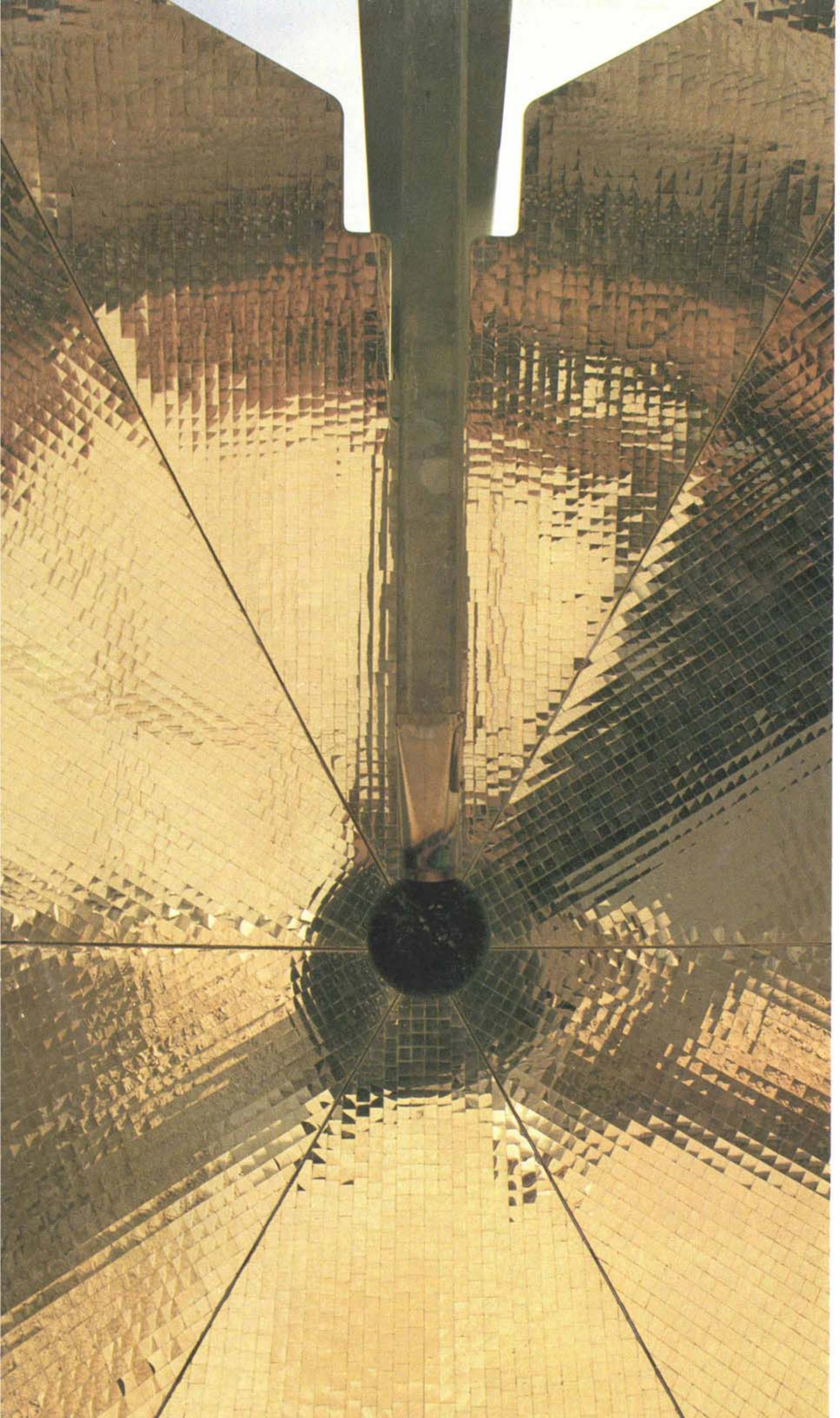

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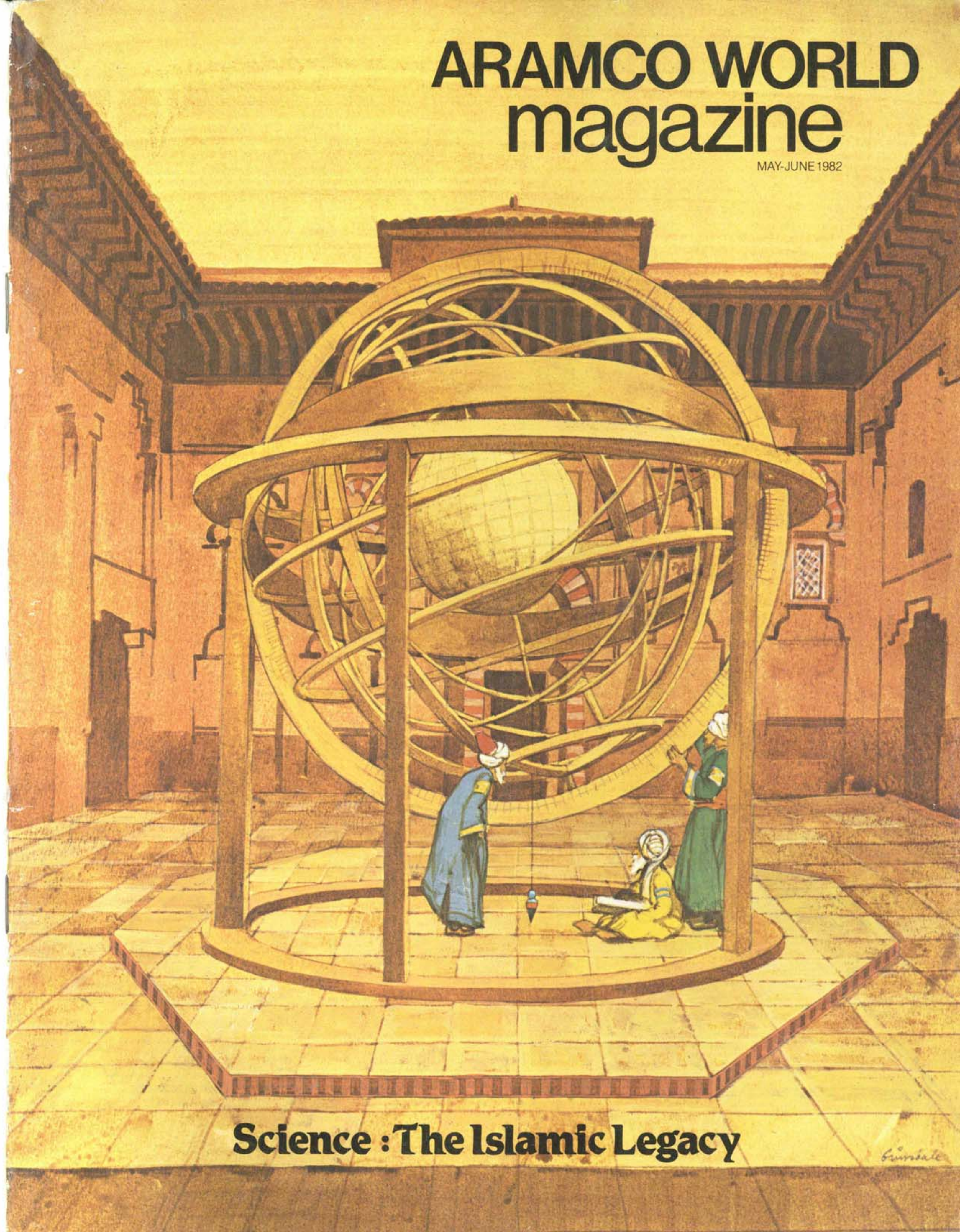
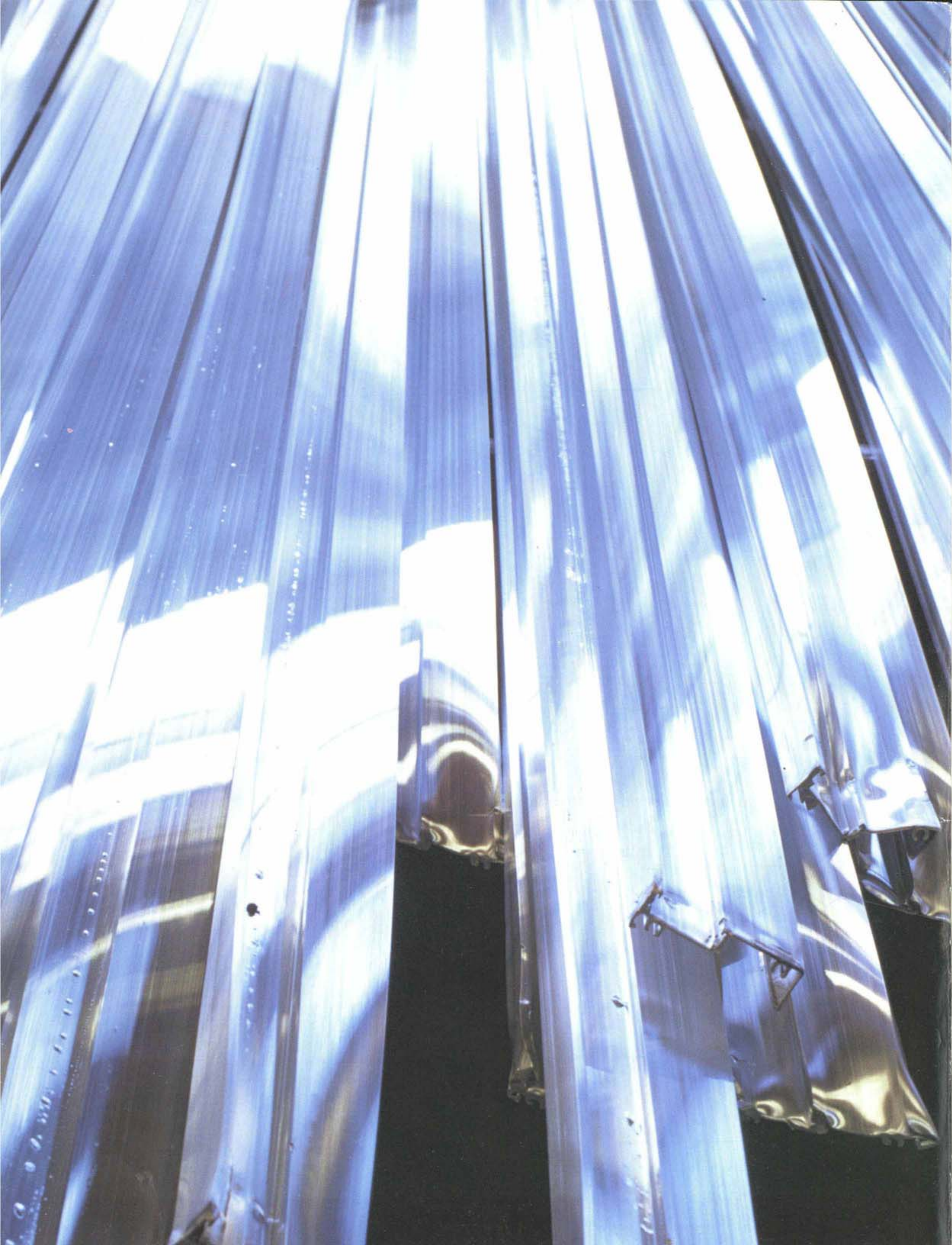


Science: The Islamic Legacy



ARAMCO WORLD magazine

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Because Saudi Arabia and Aramco – the Arabian American Oil Company – have been so closely associated with petroleum, one of the world's chief sources of energy – and with each other – it is particularly appropriate that this special issue of *Aramco World magazine* be devoted to the story of Islamic science in both the Golden Age and the modern age. It is petroleum – in Saudi Arabia, Kuwait, the United Arab Emirates and other Islamic countries – that is funding what may yet be a significant resurgence in science and technology throughout these regions – and what is already a massive effort to provide scholars and technicians for the resurgence. It is also timely. This month, in Tennessee, the Knoxville World's Fair – the Knoxville International Energy Exposition – opens to an expected crowd of millions.

No one issue could possibly cover the full history of Islamic science, of course; the scientific achievements of the Golden Age of Islam are too numerous and too diverse. Nor is it easy to summarize the scientific revival in the Islamic world today, since it includes elements from technology as well as science and seems to be cropping up in most unexpected ways – and places – and since the data is too diffuse and too raw to evaluate. Instead, therefore, we have chosen to present highlights from history and samplings of present developments. We are fully aware that they are neither complete nor comprehensive, but hope that they will suggest, nonetheless, the accomplishments of the past and the hopes of the future.

– The Editors

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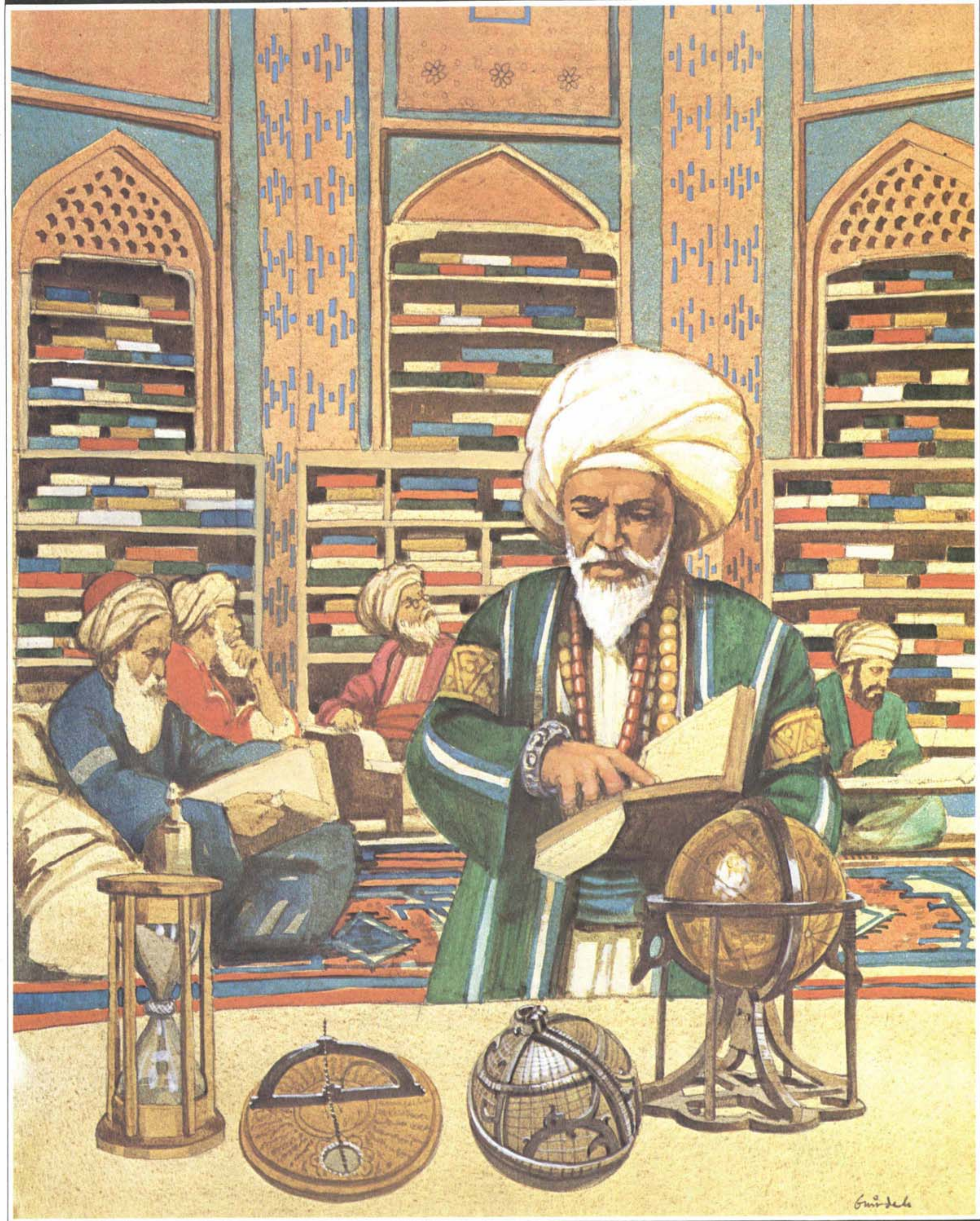
Cover: In Islamic Spain, Islam's Golden Age was at first imitated, then exceeded, as scholars poured in from the Muslim east. One example is the ninth-century scholar 'Abbas ibn Firnas who experimented with flight 699 years before Leonardo da Vinci and constructed a planetarium in which the planets revolved. This reconstruction by Michael Grimsdale, based on descriptions dating to that era, suggests the elaborate gearing that Ibn Firnas had to have developed. Back cover: In this photo by Burnett H. Moody, Kuwait solar energy experiments suggest the level of science and technology already achieved in the Gulf.



Science: The Islamic Legacy

WRITTEN BY PAUL LUNDE PAINTING BY MICHAEL GRIMSDALE
REPRODUCTION FROM *THE BOOK OF ANIMALS* COURTESY THE AMBROSIANA LIBRARY, MILAN

The Arabs were the inheritors of the scientific tradition of late antiquity. They preserved it, elaborated it, and, finally, passed it on to Europe.

The story of how this came about is far from simple, and much research needs to be done before its details are completely understood, but the broad outlines are clear.

When Egypt, Palestine, Syria, Iraq, Asia Minor and Persia fell to Islamic forces in the seventh century they included a heterogeneous population. Although the cultivated classes of the former provinces of the Byzantine Empire spoke Greek, the people spoke a number of other languages – Coptic in Egypt and various Aramaic dialects in Syria and Iraq. These populations were for the most part Christian. In Persia, the majority language was Pahlavi – an earlier form of the language spoken there today – and the state religion was Zoroastrianism, with substantial Christian minorities and a few centers of Buddhism.

Throughout this immense area, there were two main scientific traditions. The first, and by far the most important, was that of Greece. The second was that of India, strongest in Persia because of the geographical proximity of the two countries.

At a surprisingly early date, the Arab ruling dynasty of the Umayyads, with its capital at Damascus, evinced an interest in Greek science. The little Umayyad audience hall and bath of Qasr 'Amra, built in the Syrian desert around A.D. 711 – only 79 years after the death of the Prophet Muhammad – contains, on the inside of the dome, a painted representation of the zodiac made on a stereographic projection, perhaps showing a familiarity with the methods of Ptolemy. The same room contains paintings of personifications of History, Poetry and Philosophy; each figure is labeled in Greek.

The interest of the Umayyads in Greek science attested by the paintings at Qasr 'Amra is confirmed by early Muslim historians, who record the experiments in alchemy made by Khalid ibn al-Yazid, a grandson of the first Umayyad caliph Mu'awiya.

Astronomy and alchemy were thus the first sciences to preoccupy the Muslims. It is noteworthy that they were also typical of the interests of the Greek scholars of late antiquity, particularly of those in Alexandria. In fact, it was to be this tradition, with its emphasis on mathematics, physics, astronomy and medicine, that was to be most fruitfully elaborated by Muslim scientists.

Although the great library of Alexandria, repository of the learning of the classical world, no longer existed at the time of the Arab conquests, the works of many of the Greek scholars who studied there now exist only in Arabic translation. How did this come about? How did the Arabs, who had little or no *direct* contact with Greek science, and in any case were unfamiliar with the Greek language, gain their very detailed knowledge of it?

The answer to this question lies in the continued presence of a Greek-speaking (or reading) educated class among the subject populations of the Muslim empire. When the Umayyad dynasty–the language of whose administration, until A.D. 699, was Greek – was supplanted by that of the Abbasids in A.D. 750, the center of the empire shifted eastward. A new capital, Baghdad, was built in Iraq on the banks of the Tigris. Here, not far from the old Persian capital of Ctesiphon, the character of the empire changed.

Although the Umayyads had made use of non-Arab, Greek-speaking civil servants, they had remained firmly Arab in their tastes and philosophy of rule, and had made little effort to attract the subject population to the religion of Islam. Now, all this was changed; the Abbasids from the beginning conceived of an Islamic polity based on religious affiliation rather than national origin. Baghdad became an international city, where Persians, Indians, Greeks, Sogdians – from beyond the Oxus – Armenians, Turks, Jews and Arabs lived side by side. This inevitably led to a mingling of varied intellectual traditions; at the same time, the language of the court – and increasingly of the people – was Arabic.

The Arabic-speaking intelligentsia of Baghdad were of course aware, through their contacts with Greek-speaking Muslims and Christians, of the great achievements of classical scientists. The university of Gondeshapur, the great intellectual center of Sassanid Persia, was not far from Baghdad. When the Council of Ephesus in 431 excommunicated Nestorius, his followers sought refuge in Persia, where the Sassanid Shahs welcomed them. The Nestorians brought with them a knowledge of two sciences which were, with their help, later to be cultivated by the Muslims – medicine and astronomy.

Science : The Islamic Legacy

Another Christian sect, the Monophysites, fleeing Byzantine persecution 20 years later, also settled in Persia, as well as in Syria, where they founded schools at Edessa, Nisibis, Antioch and Beirut, where law and rhetoric were particularly studied. These two disciplines were also later to become fruitful areas of Muslim scholarship.

There was, therefore, no complete rupture between the late classical and the Muslim world, as far as the scientific tradition was concerned. A Greek-speaking physician like Alexander of Tralles, who was active at about the time the Prophet Muhammad was born – around A.D. 570 – wrote a standard medical textbook which was later translated into Arabic and eventually from Arabic into Latin, and had considerable influence on medieval European medical practice. One of the most striking confirmations of this continuity is the fact that the Alexandrian Academy survived, albeit in shadowy form, into Islamic times, when it was moved to Antioch, where enrollment fell until only one professor and two students were left. One of these students in turn taught one of the foremost Abbasid translators, while the other taught a student who in turn instructed one of the greatest Arab philosophers, al-Farabi.

The Indian scientific tradition mingled with that of Greece at Gondeshapur and other centers of Christian learning in Persia. The Indians were particularly concerned with mathematics, astrology and the scientific study of grammar. About the year 600 – during the lifetime of the Prophet Muhammad – Indian mathematicians developed the symbol zero and the system of place notation. This invention, first mentioned in the Islamic cultural area in a Syriac text written in A.D. 662, when the Umayyad caliph Mu'awiya was ruling in Damascus, revolutionized the study of mathematics and made possible the great achievements of Muslim mathematicians.

It was during the early Abbasid period, however, that the tentative beginnings made under the Umayyads blossomed into a true scientific renaissance. Several of the early Abbasid caliphs made a systematic effort to translate Greek and Indian scientific texts into Arabic.

This effort began during the reign of the second Abbasid caliph, al-Mansur, who founded Baghdad and ruled from A.D. 754 to 775. Al-Mansur sent embassies to the Byzantine emperor to ask for Greek mathematical texts – in particular for the *Elements* of Euclid; the famous al-Ma'mun, later did the same. Ibn Khaldun, writing in North Africa in the 14th century, but making use of a wide variety of earlier sources, describes the remarkable efforts made by these caliphs to enrich the intellectual life of the Muslim community:

> When the Byzantine emperors conquered Syria, the scientific works of the Greeks were still in existence. Then God brought Islam, and the Muslims won their remarkable victories, conquering the Byzantines as well as all other nations. At first, the Muslims were simple, and did not cultivate learning, but as time went on, and the Muslim dynasty flourished, the Muslims developed an urban culture which surpassed that of any other nation.
>
> They began to wish to study the various branches of philosophy, of whose existence they knew from their contact with bishops and priests among their Christian subjects. In any case, man has always had a penchant for intellectual speculation. The Caliph al-Mansur therefore sent an embassy to the Byzantine emperor, asking him to send him translations of books on mathematics. The emperor sent him Euclid's *Elements* and some works on physics.
>
> Muslim scholars studied these books, and their desire to obtain others was whetted. When al-Ma'mun, who had some scientific knowledge, assumed the caliphate, he wished to do something to further the progress of science. For that purpose, he sent ambassadors and translators to the Byzantine empire, in order to search out works on the Greek sciences and have them translated into Arabic. As a result of these efforts, a great deal of material was gathered and preserved.

Other Muslim historians record the arrival of an Indian scientist named Manka at the Abbasid court in A.D. 770, and he seems to have had a considerable influence on the mathematicians and astrologers of Baghdad, although we know little of the precise nature of this influence.

Under al-Ma'mun, a more systematic effort was made to translate Greek scientific texts into Arabic. He founded an institute for the purpose, called the *Bait al-Hikma,* The House of Wisdom, and staffed it with salaried Christian and Muslim scholars. The work of translation was complex. Christian translators first rendered the Greek texts into Syriac, the language with which they were most familiar. These preliminary versions were then put into Arabic, with Muslim Arabic-speakers correcting them for style.

Muslim scientists were much influenced by the Greek notion that the science of mathematics was the key to all other sciences. Aristotle, whom the Arabs called "The Foremost Teacher," had inscribed above the door of his house: "Let no one enter who does not have a knowledge of mathematics." This could equally well serve as a motto for the House of Wisdom. We have seen that one of the first Greek books brought to Baghdad from Constantinople was a copy of Euclid's *Elements.* This was translated into Arabic a number of times, as were several of the Greek commentaries upon it, in particular that of the inventor and mathematician, Hero of Alexandria, whose experiments with automata in the third century B.C. were to be so strangely echoed by Muslim scientists. As late as the 13th-century, Nasir al-Din al-Tusi wrote a detailed commentary on the *Elements,* which was among the first Arabic texts to be printed in the original in 16th-century Italy.

Many other Greek mathematical works found their way into Arabic through the efforts of the scholars at the House of Wisdom and their successors. Euclid, Apollonius of Perga, Nichomachus of Gerasa – the magnificent classical ruin presently called Jerash, in Jordan – Menelaus, Archimedes and Theodosius of Tripoli were all translated at an early date, as were works by astronomers like Ptolemy, Autolycus, Dorotheus, Aristarchus, Hipparchus, Theon of Alexandria, Aratus and Geminus of Rhodes. A number of these works were later translated into Latin and Hebrew and thus became known to medieval Europe.

The exact sciences – mathematics, astronomy and optics – perhaps occupied pride of place for Muslim scholars, but the natural sciences, particularly medicine and its ancillary disciplines, were also assiduously cultivated. Again, the first phase was

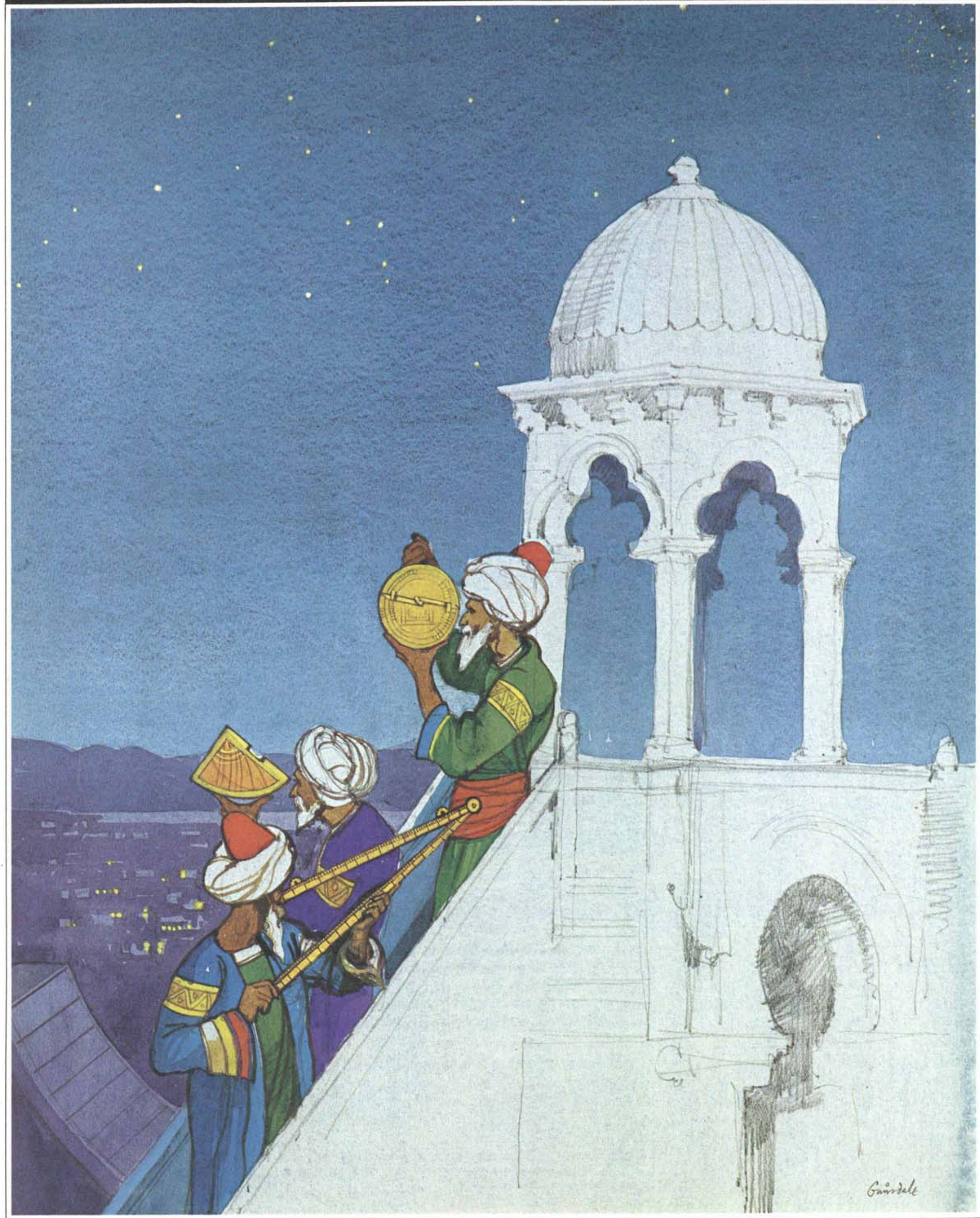
translation of Greek medical writings – particularly those by or attributed to Galen and Hippocrates – into Arabic. There then followed a period of original research by Muslim scientists, often leading to major revisions of the received tradition, and finally a period of codification in which the results of previous research were incorporated into convenient handbooks. Botany, particularly in so far as it was related to *materia medica,* received its first impetus from an illuminated copy of Dioscorides sent by the Byzantine emperor to the Abbasid court; this fundamental classical work was quickly rendered into Arabic, and many corrections and new plant identifications were added to it, particularly by scholars in North Africa and Muslim Spain. It was in Spain too that the first scientific works on agronomy were composed, works that are a prime source for our knowledge of medieval agricultural techniques in the Muslim world – techniques that were passed to Europe and greatly increased productivity.

Aristotle's work *Generation of Animals* was early translated into Arabic, and was made use of by al-Jahiz in his amusing *Book of Animals,* which includes a great deal of linguistic, literary and historical information in addition to passages of accurate, if amusing, scientific observation. Various handbooks of veterinary medicine were also composed, although these have so far received little attention from scholars.

Very few works of Greek science failed to find their way into Arabic during the Abbasid period. For one of the few times in human history, a culture with its own language, religion and customs embarked upon the extraordinary task of translating an alien intellectual tradition into its own language and fitting it into its own conceptual framework. In the process, old errors were corrected, and the experimental method, the basis of all scientific progress, was clearly enunciated. For one of the great achievements of medieval Muslim scientists was their willingness to correct the texts they transmitted. Just as they recomputed the circumference of the earth, and corrected the geographical information in Ptolemy on the basis of their own observations, so they dared question even Aristotle.

The works of Muslim scientists reached medieval Europe through Latin and Hebrew translations, for the most part made in Spain and somewhat later in Sicily. As early as the 10th century, astronomical works were being translated into Latin in Catalonia, and perhaps elsewhere in Spain. Later, during the 12th and 13th centuries, the works of Avicenna (Ibn Sina), Averroes (Ibn Rushd), Avempace (Ibn Bajja) and a host of others were translated into Latin and in the 13th century, at the court of Alfonso the Wise, into Spanish. At the very time that Baghdad fell to the Mongols, in 1258, and the Abbasid caliphate came to an end, scribes in Europe were preserving the Muslim scientific tradition. This is why, just as many Greek texts now survive only in Arabic dress, many Arabic scientific works only survive in Latin.

It is upon this tenuous and almost miraculous line of transmission that the scientific achievements of the modern world are based: the work of scholars of many different religious and linguistic backgrounds carefully transmitting, correcting and adding to a tradition that stretches back to Aristotle and beyond, each bound to his predecessor by a shared devotion to truth. ■



SCIENCE IN THE GOLDEN AGE

WRITTEN BY PAUL LUNDE. PAINTINGS BY MICHAEL GRIMSDALE.
ILLUSTRATIONS COURTESY THE BODLEIAN LIBRARY.

Towards the end of the 10th century, Ibn al-Nadim, son of a Baghdad bookseller and boon companion of Abbasid caliphs, compiled an annotated bibliography of books that had passed through his hands during the course of his long and active life. The sheer number of books that he lists, to say nothing of the range of their subject matter, is astonishing: Aristotle appears beside Sindbad the Sailor, Euclid beside the stories of Goha, Plato beside the poems of 'Antar ibn Shaddad.

The most striking feature of Ibn al-Nadim's catalog, however, is the number of books dealing with science. In a chapter entitled *The Reason Why Books on Philosophy and Other Ancient Sciences Became Plentiful in This Country,* Ibn al-Nadim relates a strange story of how Aristotle appeared in a dream to the Caliph al-Ma'mun and assured him that there was no conflict between reason and revelation. Thus reassured, al-Ma'mun set about obtaining the works of the Greek philosophers, the first step toward founding the famous House of Wisdom, a center for the translation of Greek scientific works into Arabic. Ibn al-Nadim told the story this way:

> This dream was one of the most definite reasons for the output of books. Between al-Ma'mun and the Byzantine emperor there was correspondence . . . so al-Ma'mun wrote to the Byzantine emperor asking his permission to obtain a selection of old scientific manuscripts, stored and treasured in the country of the Byzantines. After first refusing, he finally complied, and al-Ma'mun sent forth a number of scholars, among them al-Hajjaj ibn Matar, Ibn al-Batrik, Salman, the director of the House of Wisdom and many others. They selected books from those they found and brought them back to al-Ma'mun, who ordered them to prepare translations of them.

Though the House of Wisdom was founded in 830, Abbasid interest in Greek science had begun almost with the founding of the dynasty in 750 and by the time the House of Wisdom was launched, that interest had already been expressed in a number of important fields. The first Arabic translations of the medical works of Galen and Hippocrates, for example, were made by the official translator of the second Abbasid caliph, al-Mansur, builder of Baghdad. These sparked the interest in medicine so characteristic of Islam.

In 809, the Caliph Harun al-Rashid founded the first hospital in the Islamic World, and within a short time no major city in the empire was without one. The translator of these medical texts died in 800 – the year that Charlemagne was crowned Holy Roman Emperor. His son, Ibn al-Batrick, was among those scholars sent by al-Ma'mun to the Byzantine court in search of manuscripts.

But why should an Abbasid caliph, upholder of the Holy Law of Islam, dream of Aristotle, pagan philosopher to an alien race? Why did the Muslim community, engaged first in the great excitement of the conquests, and later in the difficult and absorbing task of administration, trouble with the science and philosophy of the Greeks, the lore of Persia and the mathematics of India?

The answers to these questions lie in the extraordinary cross-fertilization of once separate intellectual traditions that occurred as a result of the Muslim conquests of the seventh and early eighth centuries. These conquests united the ancient civilizations of the Middle East – to say nothing of North Africa and Spain – under a single rule for the first time since Alexander the Great, and Baghdad, from its foundation in 763, became a meeting place for Persians, Greeks, Indians, Copts, Berbers, Sogdians, Turks and even Chinese.

These people spoke many different languages, represented a great variety of cultures and an even wider variety of religions. Jews, Christians – of every possible variety – Manicheans, Hindus, Buddhists and even pagans jostled each other in the streets of the new capital. Yet the Abbasids, who tended to encourage talented men whatever their origin, absorbed them all and they, eager to contribute their talents helped to transform the empire.

The most single striking effect of the unification – of Anatolia, Iran, Syria, Iraq, Egypt, Palestine, North Africa and Spain – under Islamic rule was the opening of formerly closed frontiers – frontiers that had been closed politically, linguistically and intellectually since the death of Alexander the Great in the fourth century B.C. The Arabic word which we translate as "conquest" literally means "openings" – *futuh* — and this was indeed the effect of the Muslim conquests. For centuries the Byzantines had been at war with the Persians; now that major political and cultural frontier had fallen and students from the ancient university at Gondeshapur were able to meet colleagues from the philosophical schools of Alexandria in the streets of Baghdad and the effects were dramatic: no less than a scientific renaissance. It was rather as if Russia

Science : The Islamic Legacy

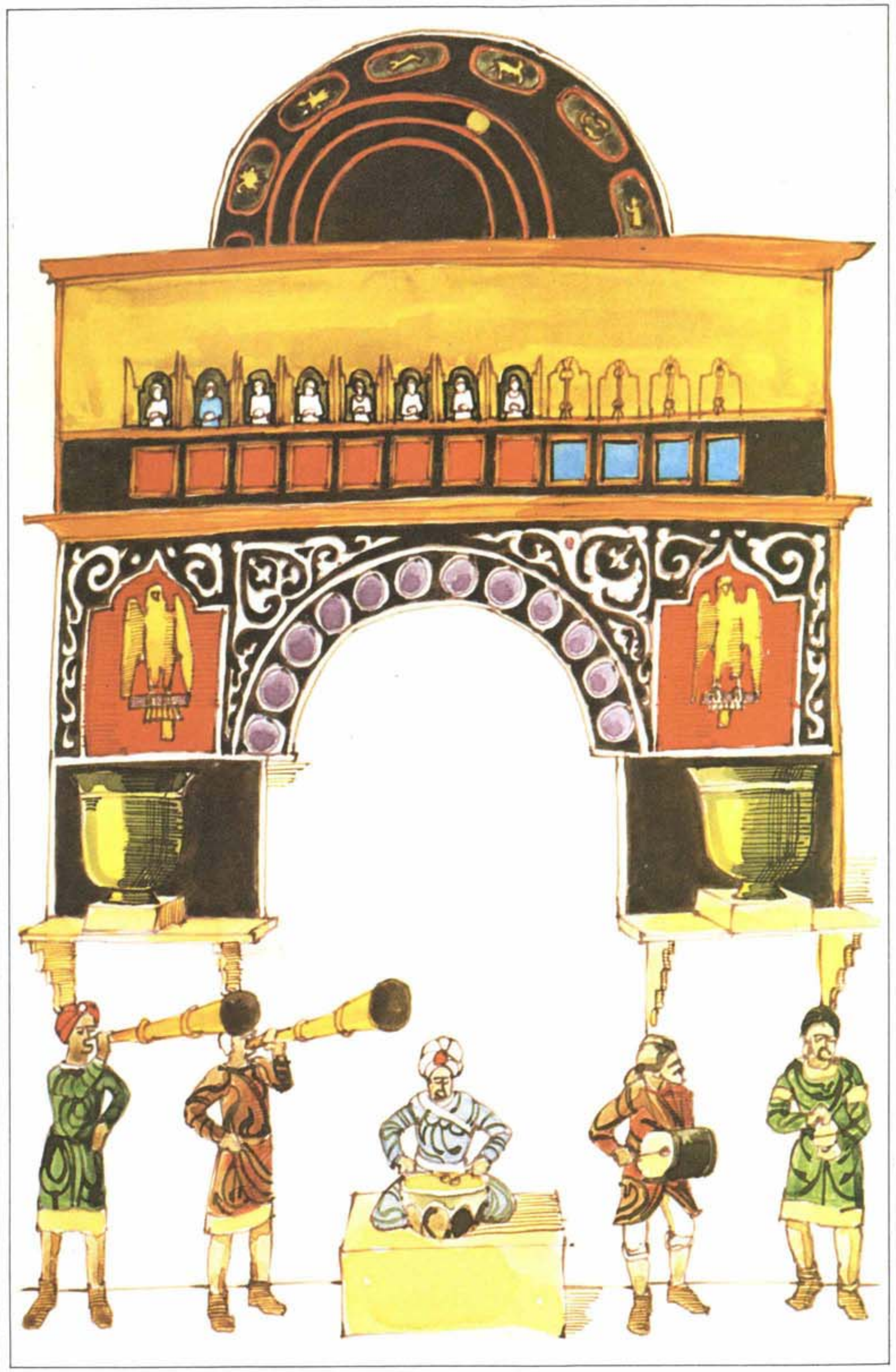
and America were to be united under the benevolent rule of a third party and able to freely exchange scientific information.

At first, contacts between scholars of such different backgrounds were limited – because of the lack of a common language. But by the time al-Ma'mun conceived the idea of the House of Wisdom, Arabic had already become the language of international scholarship as well as the language of Divine Revelation – and this was one of the most significant events in the history of ideas. Greek, long the language of philosophical and scientific inquiry, gave way to Arabic, and it was through the lens of Arabic that Western scholars, after the long half-light of the Dark Ages, first looked on the pages of Plato and Aristotle.

Another intellectual strand which was woven into the pattern of Islamic intellectual life during the early Abbasid period was that of Persia. The Abbasid movement had its origin in Khorasan, and particularly in the oasis of Marv (now in the Soviet Union), which had been the home of a medical school under the Sassanids. The Barmakid family, which supplied the Abbasid caliphs with their advisors and prime ministers from 750 until 803, was responsible for fostering translations from Pahlavi historical and scientific works into Arabic. It was through Pahlavi that the Arabs first came into contact with the learning of India, which had a long tradition of intellectual activity in the fields of astronomy, medicine and mathematics.

The Barmakids were also responsible for establishing the first paper mill in Baghdad.

Until the capture of Chinese paper makers by Muslim forces at the Battle of Talas in 751, precious books – such as the Koran – had been written on parchment, while papyrus was used for ephemeral government documents. Neither was very suitable, parchment because its price was prohibitive, papyrus because it decayed in the damper, colder climates outside its native home of Egypt. Paper, on the other hand, was the perfect writing material: cheap, long-lasting and attractive. This "invention" – for so it was – had an effect on education and scholarship as important as the invention of printing in the 15th century. Books were now within the reach of everyone, and soon schools were attached to most mosques, and libraries became common.



Unlike the Byzantines, with their suspicion of classical science and philosophy, the Muslims were actively enjoined by the Traditions – the *dicta* of the Prophet – to "seek learning, though it be in China." Another well-known Tradition states: "The search for knowledge is obligatory for every Muslim"; another that "The ink of scholars is worth more than the blood of martyrs."

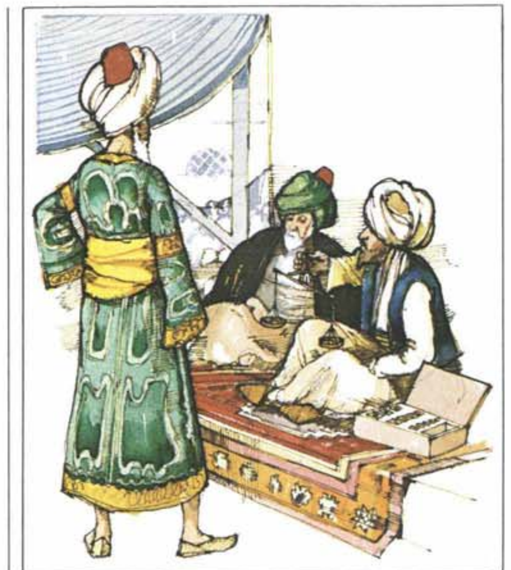
In obedience to these injunctions, the first generations of Muslim scholars had devoted themselves to making the language of the Koran a vehicle for the expression of scientific ideas. Now, with the establishment of the House of Wisdom, with its library and staff of scholar-translators, the work could begin.

The job that lay before these men was Herculean. It was nothing less than the transfer of what had survived of the philosophical and scientific tradition of the ancient world – first into the Arabic language, and then into the conceptual framework of Islam. In the process, old errors were corrected and the experimental method, the basis of all scientific progress, was clearly enunciated.

According to a tradition which early Muslim scholars loved to quote, Aristotle had inscribed above the door of his house: "Let no one enter who does not have a knowledge of mathematics." This science, together with logic, its handmaiden, was seen as the basis of all others and al-Farabi, the great Arab philosopher, who died in 950, placed logic and mathematics near the head of his *Catalog of Sciences* – a book which in its Latin translation had a considerable influence upon the curricula of medieval European universities. He arranged the sciences as follows : (1) the linguistic sciences (2) logic (3) mathematics (4) physics (5) metaphysics (6) politics (7) jurisprudence and (8) theology.

Accordingly, al-Hajjaj ibn Yusuf ibn Matar, who accompanied the first embassy to the Byzantine court, brought back a copy of Euclid's *Elements* and made two translations, one for the Caliph Harun al-Rashid and the other for al-Ma'mun. These translations served as the basis for a critical edition prepared by two of the most famous translators associated with the House of Wisdom, Ishaq ibn Hunain and Thabit ibn Qurra. Muslim scholars also translated a commentary to Euclid by Hero of Alexandria, the third century B.C. inventor and mathematician, who developed a prototype of the steam engine.

This was not the only work on Euclid to find its way into Arabic. Translations were also prepared of works either by Euclid or attributed to him on the subjects of optics, music, ethics, logic and weights and measures. The foundations laid by these translations of Euclid were buttressed not only by the translation of Hero's commentaries, but by at least 11 major works by Archimedes, including a treatise on the construction of a water-clock. Nicho-



machus of Gerasa (Jerash) had written a book on number theory in the second century, heavily influenced by Pythagorean theories, and this provided the basis for some of the more arcane Islamic speculations in this field. Other late classical mathematicians, men like Theodosius of Tripoli, Apollonius of Perga, Theon and Menelaus were also translated into Syriac and/or Arabic by the staff of the House of Wisdom.

Armed with these translations, as well as certain Indian works, the great age of Islamic mathematical speculation began. Its early development was intimately linked with two other disciplines based upon it: astronomy and music, or the science of harmonics.

The first great advance on the inherited mathematical tradition was the introduction of Arabic numerals. Scholars working at the House of Wisdom first became aware of them in translations of Indian astronomical works, and hence called them "Indian." These numerals embodied the place-value theory which allowed numbers to be expressed by nine figures plus zero (Arabic *sifr*, "cipher") and not only simplified calculation of all sorts but made possible the development of algebra.

Muhammad ibn Musa al-Khwarizmi, born in the town now called Khiva, seems to have been the first to systematically explore their use in his book, *Addition and Subtraction in Indian Arithmetic,* later translated at Toledo into Latin under the title *Algorismi de numero indorum* and introduced as "Arabic numerals" into the West. Al-Khwarizmi used both Greek and Indian sources and their cross fertilization led to his famous *Kitab al-Jabr wa al-Muqabala,* the first book on algebra; the word "algebra" is derived from the second word in his title and originally meant "bone-setting." Al-Khwarizmi used it as a graphic description of one of the two operations he uses to solve quadratic equations.

Interest in geometry began with the translation, as we have seen, of Euclid's *Elements.* The Islamic world responded to geometry even more whole-heartedly than it had to algebra, as the beautifully drawn geometric proofs which adorn the pages of Arabic manuscripts on the subject attest. Its study influenced both architecture and the decorative arts and Ibn Khaldun recommended the study of geometry as good training in logical thought:

> Geometry is useful because it enlightens the intelligence of the man who cultivates it and gives him the habit of thinking exactly. Indeed, all the geometrical proofs are characterized by the clarity of their arrangement and by the evidence of their systematic order. That order and that arrangement make it impossible for any error to creep into the argument. Therefore the minds of people who are engaged in these studies are not in danger of being deceived and their intelligence is sharpened.

The great North African historian, in a striking and homely image, goes on to say that the study of mathematics in general "is like soap for the clothes, which washes away the dirt and cleans the spots and stains."

The men most responsible for encouraging the study of geometry were the sons of Musa ibn Shakir, al-Ma'mun's court astronomer. These three men – Muhammad, Ahmad and al-Hasan – devoted their lives and fortunes to the quest for knowledge. Their devotion to the cause of science is all the more remarkable by virtue of the fact that they were private citizens; their interest in these matters shows how widely the scientific renaissance of the ninth century reached. Ibn al-Nadim says of them:

> These men were some of those who took extreme pains to study the ancient sciences, for the sake of which they gave generously what was required, taxing themselves with fatigue. They dispatched to the Byzantine country men who sent scientific manuscripts back to them.

They hired translators from various districts and kept them in attendance for many years, so that they brought to light wonders of learning. The sciences in which they were most interested were geometry, mechanics, dynamics, music and astronomy.

The "Banu Musa", or "Sons of Musa," as they were called, not only sponsored translations of Greek works, but wrote a series of important original studies of their own: The impressive title of one of their works by Muhammad Ibn Musa reads: *The Measurement of the Sphere, Trisection of the Angle, and Determination of Two Mean Proportionals to Form a Single Division Between Two Given Quantities.* His interests were not limited to geometry, however; he also wrote works on celestial mechanics, the atom, the origin of the earth, and an essay on the Ptolemaic universe. His brother Ahmad wrote a fundamental work on mechanics, while al-Hasan wrote a study of the geometrical properties of the elipse. Al-Hasan was perhaps the most gifted geometrician of his time. He translated the first six books of Euclid's *Elements* and is said not to have finished it because he was by then able to work out the remaining propositions himself.

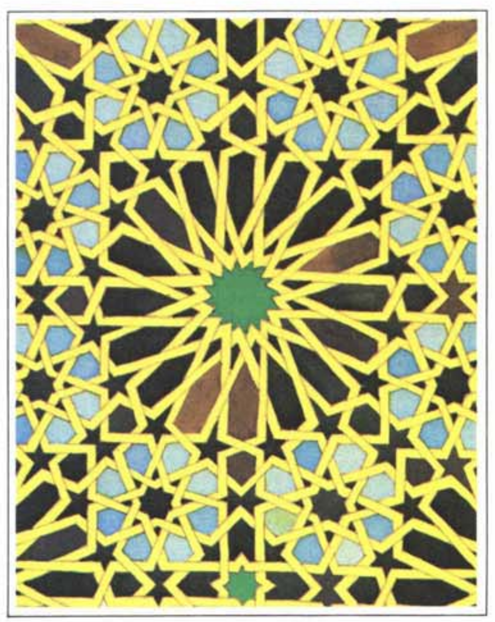
In terms of influence on mathematics in the West, the most important work of the Banu Musa was *On the Measurement of Plane and Spherical Figures,* which was translated in the 12th century by Gerard of Cremona under the title *Verba filiorum Moysi filii Sekir, id est Maumeti, Hameti, Hasan.*

The Banu Musa served a number of caliphs and occasionally were even involved in practical projects such as the construction of a canal. They were also famous for discovering perhaps the greatest of the scholars of the ninth century, Thabit ibn Qurra. While returning from a trip to Byzantium in search of manuscripts, Muhammad ibn Musa stopped in the town of Harran, where he met Thabit ibn Qurra, working as a money changer. Muhammad was so struck by Thabit's mastery of Syriac, Greek and Arabic that he persuaded Thabit to go to Baghdad – where such talents would find a suitable reward. There, Muhammad personally presented his *protégé* to the Caliph al-Mu'tadid, who was so struck in his turn by Thabit's learning and intelligence that he appointed him court astrologer.

To the small coterie of scholars at the House of Wisdom, Thabit was invaluable, if only because his knowledge of Greek and Syriac was unrivaled. This latter language was important, for in many cases the writings of the Greek scientists were either preserved in Syriac versions, made by Nestorian scholars of Iraq and Persia, or more frequently translated first into Syriac and then into Arabic. The reason for this was that the Christian communities, whose language was Syriac, tended to know Greek but not Arabic, while Muslim scholars found it easier to acquire a knowledge of Syriac, which is closely related to Arabic, than they did to learn Greek.

Most early translations prepared under the auspices of the House of Wisdom were done in this way, through the cooperation of teams of scholars of different religious and linguistic backgrounds. Thabit's success was due as much to his linguistic abilities in the three major languages as to his very great natural gifts.

Thabit immediately set about correcting some of the earlier translations of important works, such as Ishaq ibn Hunain's



editions of Ptolemy's *Almagest* and Euclid's *Elements.* His translations of key works by Archimedes, such as the famous *Measurement of the Circle,* were done into Latin in the 12th century by the indefatigable Gerard of Cremona, a worthy successor to Thabit.

Thabit also wrote more than 70 original works in the fields of mathematics, astronomy, astrology, ethics, mechanics, music, medicine, physics, philosophy and the construction of scientific instruments. He wrote valuable commentaries on Aristotle, Ptolemy and Euclid, as well as a series of introductions to other Greek thinkers.

Finally, his sons formed a dynasty of scholars that lasted to the end of the 10th century. His son Sinan was the most famous physician in Baghdad, director of several hospitals and court physician to three successive caliphs. He was an author as well, and wrote books on history, mathematics, astronomy and politics.

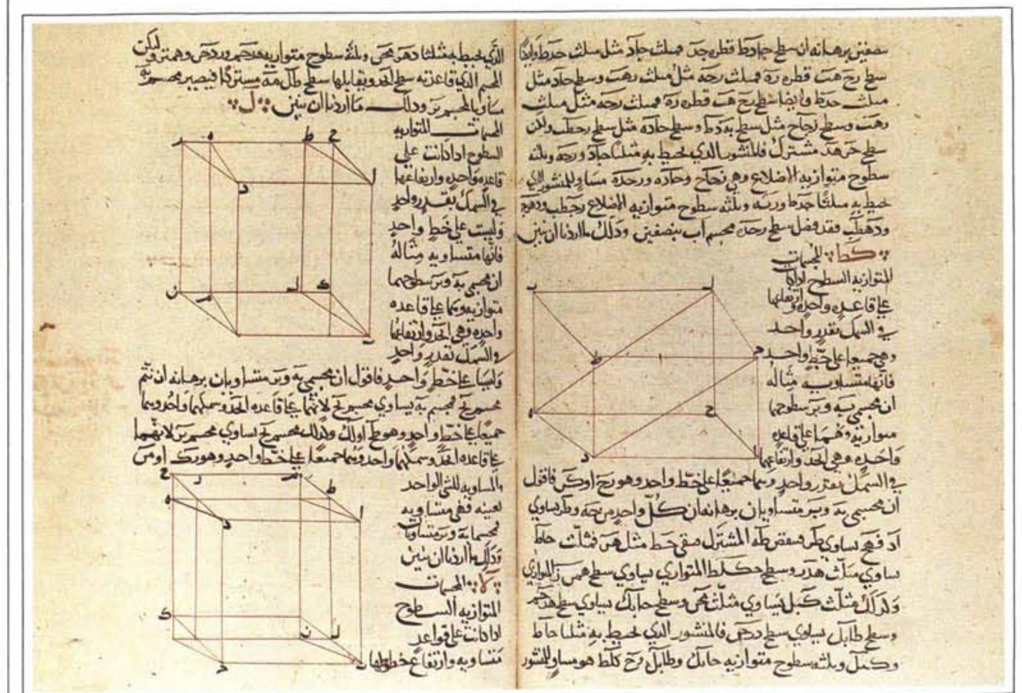
His son, Ibrahim ibn Sinan ibn Thabit, was also a prominent scientist, perhaps better known as an instrument maker. When Ibrahim was 17 years old, he first became interested in various ways of reckoning time by the sun, and wrote a systematic treatise on the construction of sundials which remained standard for many years. One of Ibrahim's brothers, Thabit, named after his grandfather, was director of various hospitals, as well as the author of a work on history.

Thabit ibn Qurra and his descendants, together with the Banu Musa, led lives of extraordinary dedication to science and were enormously productive. The effect of both their translations and their original works – on their own and succeeding generations of scholars – was pervasive.

The Banu Musa and Thabit ibn Qurra and his sons did not work in isolation. The works that issued from the House of Wisdom were the product of many different men – linguists, editors, researchers, scribes and technical advisors. We unfortunately know little about how the House of Wisdom was organized. But we do know that these scholars developed certain academic techniques, such as collating as many different manuscripts of a given work as possible in order to establish a critical text, glossaries, annotations written in the margin of the page and the compilation of dictionaries of technical terms. These techniques are still basic to all academic research. Ibn al-Nadim lists 57 translators who were associated with the House of Wisdom and says that the running costs of the organization, including maintenance, came to 500 gold dinars a month.

Two other men also played critical roles in the transmission of Greek learning to the Muslim world: Hunain ibn Ishaq – known to the Latin west as Joanitius – and Qusta ibn Luqa, from Baalbek.

Born near al-Hira, the old capital of the Lakhmid dynasty in Iraq, Hunain ibn Ishaq was the son of an apothecary, who, recog-



nizing his son's bent for medical studies, sent him to Baghdad. In the capital, Hunain found powerful supporters in the Banu Musa and set about learning Greek, and was soon translating the entire canon of Greek medical works into Arabic – including Galen, Hippocrates and the famous Hippocratic oath, obligatory then for Muslim physicians as it is everywhere today. Hunain was in many ways the most gifted of the translators associated with the House of Wisdom. His scholarly methods were impeccable, and he tended to translate more freely than many of the others, whose translations tended to err on the side of literalism – sometimes to the point of virtual incomprehensibility by those who did not know the original text.

Hunain also wrote at least 29 original treatises on medical topics. The most significant of these was a collection of 10 essays on ophthalmology. This work covers, in systematic fashion, the anatomy and physiology of the eye and the treatment of various diseases which afflict the vision. It is the first Arabic medical work to include anatomical drawings, and those that illustrate surviving manuscripts are very accurately drawn. This book was translated into Latin and for centuries remained the authoritative treatment of the subject in both Western and Eastern universities.

Hunain lived a life of exemplary piety and by his example did much to lend dignity to the medical profession. The Caliph al-Mutawakkil, seeking to test Hunain's integrity, ordered him to prepare a poison; "I have learned only the actions of beneficial drugs, confident that this is all that the Commander of the Faithful would want of me," replied Hunain, and was rewarded by being made the director of the House of Wisdom.

Qusta ibn Luqa was also an accomplished translator and scholar. Ibn al-Nadim, in fact, considered him an even better translator than Hunain, and says: "He was never subject to criticism, being a master of literary style in the Greek tongue and excelling also in Arabic diction." Qusta wrote some 40 original works on an intriguing variety of subjects: politics, medicine, "burning mirrors," insomnia, paralysis, diseases which affect the hair, fans, the cause of wind, an introduction to logic, a book of anecdotes about the Greek philosophers, dyes, nutrition, an introduction to geometry, astronomy and "The Bath," to mention only a few.

Yuhanna ibn Masawaih was one of the early directors of the House of Wisdom. He served under four caliphs – al-Ma'mun, al-Mu'tasim, al-Wathiq and al-Mutawakkil. He wrote almost exclusively about medical problems, in particular gynecology. Ibn al-Nadim related the following anecdote, which shows that the scholarly milieu of ninth century Baghdad was not unrelievedly serious:

> Ibn al-Hamdun, the court companion, made fun of Ibn Masawaih in the presence of al-Mutawakkil, whereupon Ibn Masawaih said to him, 'If in the place of your ignorance there were intelligence, it could be divided among a hundred black beetles so that each one of them would be more intelligent than Aristotle.'

Perhaps the greatest of the ninth century physicians was Abu Bakr Muhammad ibn Zakariya al-Razi, from the important Iranian town of Rayy. Al-Razi, known to the West as Rhazes, wrote, according to a bibliography of his writings compiled by al-Biruni in the 11th century, 184 works. Fifty-six of these dealt with medical topics. Al-Razi was deeply versed in the classical medical tradition, as it had been made accessible in the translations that poured forth from the House of Wisdom, but his originality lay in his open advocacy of experiment and observation.

The authority of the Greek philosophers and scientists was so great that lesser men were content to accept their views without question. Not al-Razi, who questioned everything, and relied more on his own observations than on received attitudes. His gigantic compendium called *al-Hawi,* "The All-Encompassing," contains al-Razi's daily observations and diagnoses. He wrote a very important work on smallpox and measles, in which he correctly differentiates their symptoms for the first time.

A friend of Ibn al-Nadim gave the following lively account of al-Razi at the height of his powers:

> When I questioned a man, one of the people of Rayy, of great age, about al-Razi, he said: 'He was an old man with a large sack-shaped head, who used to sit in his clinic with students around him... a patient would enter and describe his symptoms to the first persons who met him. If they had knowledge of what was wrong, good; but if they did not, he would pass from them to others. Then, if they hit upon the diagnosis, good; but if not, al-Razi himself would discuss the case. He was generous, distinguished and upright with the people. He was so kindly, compassionate with the poor and the sick that he used to bring them substantial rations and provide nursing for them... He was never found when not taking notes or transcribing them, whether to make a rough draft or a revised copy'.

Science : The Islamic Legacy

It is impossible to give an adequate idea of the range of al-Razi's thinking, even in the field of medicine (he was a philosopher and mathematician as well as a physician) but two titles give us a sense of the man's wit and common sense: *The Reason Why Some Persons and the Common People Leave a Physician Even if He Is Clever* and *A Clever Physician Does Not Have the Power to Heal All Diseases, For That Is Not Within The Realm of Possibility.*

Unlike their modern counterparts, these Muslim scholars did not specialize. They investigated any subject that interested them, for they regarded all fields of knowledge as essentially one. Perhaps the best illustration of this is al-Kindi, "The Philosopher of the Arabs," of whom Ibn al-Nadim says: "He was the most distinguished man of his time and unrivaled during his period for his knowledge of the ancient sciences as a whole."

Al-Kindi was the first Muslim philosopher to show that there was no essential conflict between Greek rationalism and Revelation. He was profoundly religious, and sought to use Aristotelian logic to support essential Islamic dogmas. But what is astonishing about al-Kindi is the range and depth of his speculations. He wrote about logic, philosophy, geometry, calculation, arithmetic, music, astronomy and a great many other things. He wrote an introduction to arithmetic as well as an almost endless list of important works: *The Use of Indian Arithmetic; That the Sphere Is the Largest of Bodily Forms and That the Circle is the Greatest of All Plane Shapes; That the Surface of the Sea is Spherical; Calculating the Azimuth on a Sphere; An Introduction to the Art of Music; Projection of Rays; An Explanation of the Cause of the Retrogression of the Stars; The Reason Why Rain Rarely Falls in Certain Places; Areas of Vaulted Chambers; How to Form a Circle Equal to the Surface of A Designated Cylinder; Determination of the Hours on a Hemisphere by Means of Geometry; The Cause of Vertigo; The Reason Why the Highest Part of the Sky is Cold, While the Part Near the Earth is Warm; The Reasons for Cloud Formations; Calculation and Making an Instrument to Determine the Distances of Heavenly Bodies, Crossbreeding the Dove, Species of the Bee* – and more.

Al-Kindi, and to a certain extent, al-Farabi, his successor, demonstrate the liveliness of Muslim thought as the 10th century drew to a close. Al-Farabi wrestled with many of the same philosophical problems as al-Kindi and wrote a book entitled *The Perfect City,* which expresses the degree to which Islam had first assimilated Greek ideas and then impressed them with its own indelible stamp. *The Perfect City* is an essay on what might be called ethical urbanism – the ideal city should be founded on moral and religious principles, and from there would flow the physical infrastructure. Al-Farabi undoubtedly had the magnificent round city of Baghdad, The City of Peace, in mind, which was consciously constructed on the pattern of the ancient cosmological cities of the east, its round form representing the Cosmos and its four gates the cardinal points of the compass.

With the death of al-Farabi in A.D. 950, the first period of Islamic scientific thought drew to a close. It had begun in 763 with the foundation of Baghdad; it had seen first the translation of the intellectual patrimony of the ancient world into Arabic, and then the first attempts to enlarge the intellectual horizons of that inheritance. Practically, the

same period witnessed the development of certain basic social institutions to a very high point – hospitals, universities, libraries, charitable institutions and public services, such as the post and water supply. During the next 300 years, although the political empire of the Abbasids would slowly fragment, the intellectual and scientific progress would continue, although now centered in provincial centers – particularly Khorasan and Spain.

A popular anecdote illustrates the intellectual background of the times. The inventor of the game of chess was granted a single request by the ruler to whom the game was first presented. The inventor's request was simple. He wanted as many grains of wheat as would result if one placed one grain on the first square of the board, two on the second, four on the third, eight on the fourth, and so on until the 64th square of the chess board. The ruler agreed to grant what seemed a modest request, but when he came to fulfill it, he discovered to his chagrin that the chess board would contain all the grain in the kingdom.

Al-Biruni, an 11th-century Persian scholar, wanted to know exactly how many grains of wheat were involved in this problem. He arrived at the figure 18,446,744,073,709,551,615, and anyone who thinks medieval computational methods primitive, should try to solve this problem without the use of a calculator.

Al-Biruni accompanied Mahmud of Ghazna's famous expedition against India in 1001. While there he learned Sanskrit and wrote a *History of India* based on native sources and his own observations. Al-Biruni's accuracy in determining the number of grains of wheat in the chessboard problem is reflected in his historical work. Like his predecessors in Baghdad, he reveals both wide-ranging interests and a concern with practical problems. For example, he is the first known writer to identify certain geologic facts, such as the formation of sedimentary rock. He was a great mathematical astronomer and was centuries ahead of his time in criticizing the Ptolemaic model of the universe.

Al-Biruni was also the author of a most detailed treatment of spherical trigonometry. Trigonometry is in fact an innovation of Muslim mathematicians, who were the first to clearly define the sine, cosine and cotangent functions. Other mathematicians, such as Nasir al-Din al-Tusi, also the author of an important work on ethics, greatly advanced mathematical theory in all branches, and 'Umar al-Khayyam, better known in the West as a poet, wrote the clearest and most elegant textbook of algebra ever produced.

Many of these advances took place as a spin-off of the consuming interest in astronomy so characteristic of Muslim lands at the time. Observatories were everywhere, and both physical and mathematical models of the universe were produced, and tables giving the distances of the fixed stars and the planets were continually refined. The size of the earth was measured to a degree of accuracy not attained again until the present century. The Muslim world, however, never abandoned the earth-centered theory of the universe which it had inherited from the Greeks.

In physics, al-Biruni and his compatriot, 'Umar al-Khayyam, both wrote on the subject of specific gravity and developed formulae for determining both the specific and the absolute weight of any object. The interest in mirrors and lenses which had engaged some scholars associated with the House of Wisdom led to sophisticated theories of optics. Ibn al-Haitham, who wrote in the 10th century, was perhaps the greatest Muslim scientist to devote himself to optics. He was the author of the most important book on the subject, *The Book of Optics,* in which he gives a detailed treatment of the anatomy of the eye. He rejected the classical notion that rays issue from the eye, and correctly stated that instead the eye receives light from the object perceived.

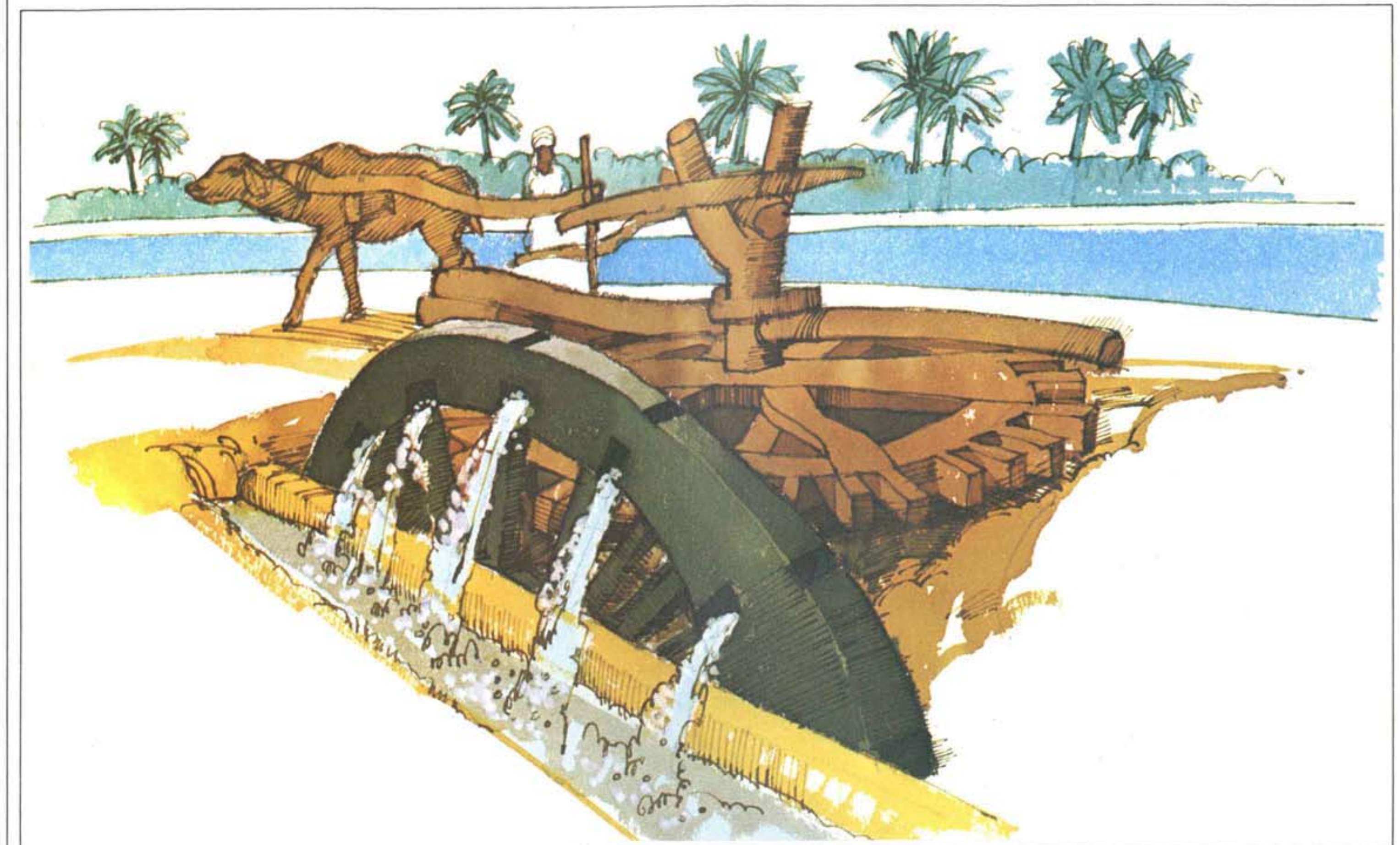
The inventiveness of later Muslim thinkers was turned to practical fields such as agriculture and irrigation. Ibn al-Haitham had proposed a plan to dam the Nile as early as the 10th century, and although this project had to wait until the 20th century to be realized, other, less ambitious projects were common. Dams, reservoirs and acqueducts were constructed throughout the Islamic world and some of these systems survive to this day. Muslim engineers perfected the water wheel, and developed many different kinds, powered by man, animals, wind, river and tide.

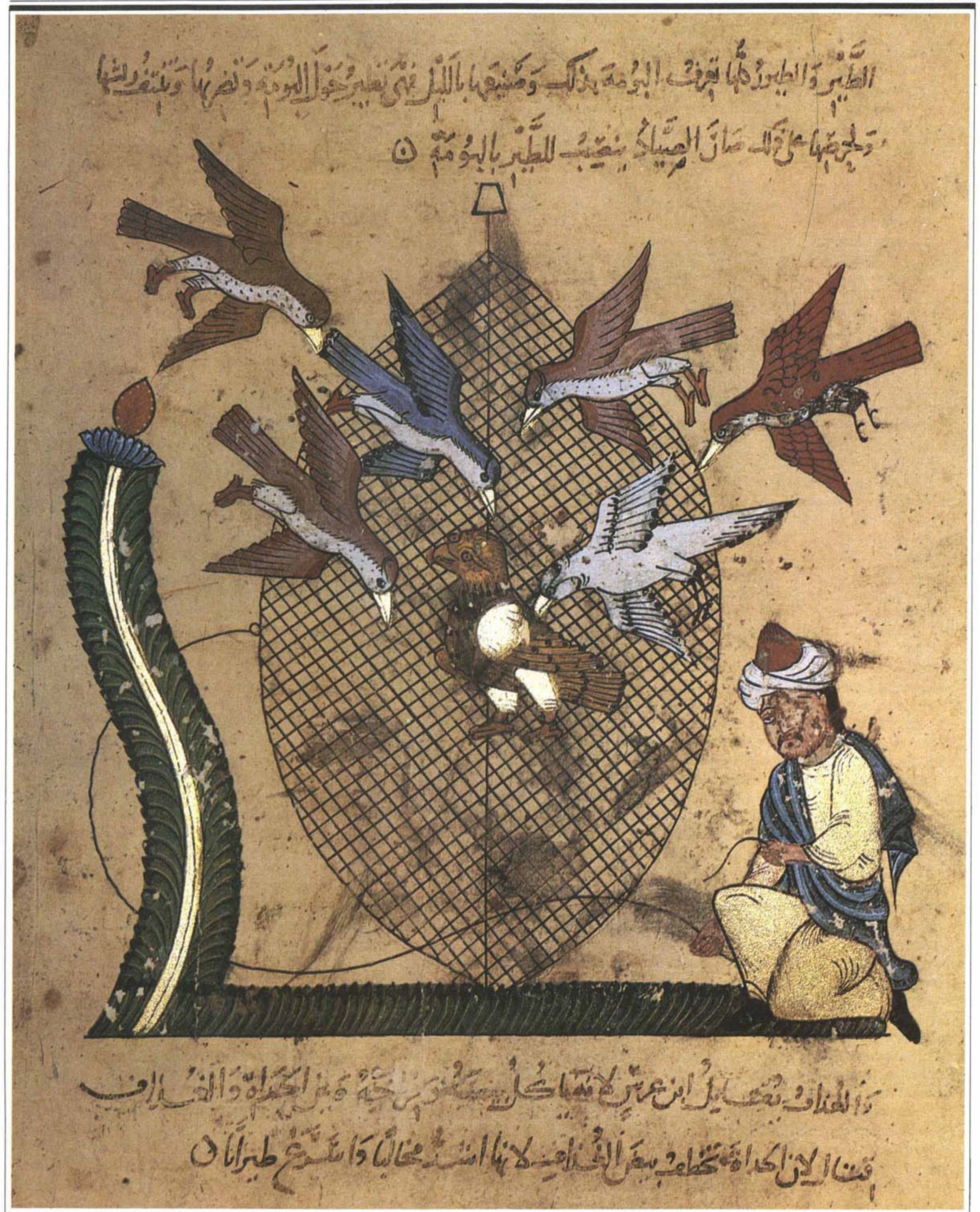
Well-digging and the construction of the elaborate underground water systems called *qanat* required a high degree of engineering skill. Some of these *qanat* are as much as 15.5 meters (50 feet) deep and they were built with a very slight inclination over a long distance in order to tap underground water. They were provided with manholes so that they could be cleaned and repaired. By being placed underground they reduced water-loss through evaporation to a minimum.

Agriculture was dependent in much of the Middle East on irrigation, and a series of important books were written on soil analysis, water and what kinds of crops were suited to what soils. The passion for new plants, both for nutritive and medicinal purposes, led to widespread plant introductions: cotton, rice, mulberry trees, citrus fruits, cherries, all of which were adapted to new soils and climates in their spread from the East to the West. The technique of grafting was carried to a high art, particularly in North Africa and Spain.

Zoology and Botany were both actively cultivated sciences, and works like al-Damiri's *Lives of the Animals* contain much interesting material. In the field of botany, Abu Hanifa al-Dinawari, a 10th century scholar, made notable contributions.

Throughout the classical period of Islam, intellectual activity in every field was vigorous, first in Baghdad, later in Cairo and the regional capitals of Anatolia, Iran and, still later, in India. The Arabs accepted the classical heritage, fertilized it with the thought of India and the East and elaborated, criticized and corrected it; they then passed it on to the West where it formed the basis for the great technological achievements that have since transformed the world. ■





THE BOOK OF ANIMALS

WRITTEN BY PAUL LUNDE
ILLUSTRATIONS REPRODUCED COURTESY THE AMBROSIANA LIBRARY, MILAN

"In every generation and among every nation, there are a few individuals with the desire to study the workings of nature; if they did not exist, those nations would perish," wrote Abu 'Uthman 'Amr ibn Bakr al-Kinani al-Fuqaimi al-Basri, better known as al-Jahiz – the Goggle-Eyed – in his magnum opus, the *Book of Animals*.

Al-Jahiz himself was one of those individuals. He lived, furthermore, during one of the most exciting epochs of intellectual history – the period of the transmission of Greek science to the Arabs and the development of Arabic prose literature – and was intimately involved in both.

Born about the year 776, some 14 years after the foundation of Baghdad by the Abbasid Caliph al-Mansur, al-Jahiz grew up in Basra, founded early in Islamic times as a garrison city, but now, along with its rival city, Kufa, a major intellectual center.

Basra contributed substantially to al-Jahiz's intellectual development. It was there that he first went to school – studying under some of the most eminent scholars of Islam. Even after he migrated to Baghdad – attracted by the greater scope of the capital – he never lost his affection for his home; after some 50 years in Baghdad, he returned to Basra, and it was there that he died. According to legend he was crushed to death by a collapsing pile of books in the year 868.

Legendary though it may be, that story illustrates an important fact about the world in which al-Jahiz lived: books were accessible. Though paper had been introduced into the Islamic world only shortly before al-Jahiz's birth, it had, by the time he was in his 30s, virtually replaced parchment.

The availability of a cheap writing material was accompanied by another social phenomenon, of which al-Jahiz himself was a product: the rise of a reading public. For the first time since the fall of the Roman Empire, the cities of the Middle East contained a large number of literate people – many of humble origins.

Al-Jahiz and his parents, for example, were poor themselves; as a young man of 20 he seems to have sold fish along one of

the Basran canals. Nevertheless, al-Jahiz learned to read and write at an early age, indicating the opportunities for what today's sociologists would call "upward mobility" in eighth-century Iraq. Al-Jahiz tells the story of how his mother presented him with a tray of paper notebooks, and told him that it would be by means of these that he would earn his living.

Al-Jahiz began his career as a writer – then, as now, a precarious profession – while still in Basra. He wrote an essay on the institution of the caliphate – which met with approval at the court in Baghdad – and from then on seems to have supported himself entirely by his pen, if we except a single three-day stint as a government clerk. The fact that he never held an official position allowed him an intellectual freedom impossible to someone connected to the court – though he did dedicate a number of his works to viziers and other powerful functionaries, and received 5,000 gold dinars from the official to whom he dedicated his *Book of Animals*.

During his long lifetime – he lived until he was 92 – al-Jahiz composed some 200 works, of varying length, on an extraordinary range of topics. Of these, only 30 or so survive today – enough nevertheless to show the omnivorous curiosity of the author. Al-Jahiz wrote *Levity and Seriousness*, *The Art of Keeping One's Mouth Shut*, *Misers*, *Early Arab Food*, *In Praise of Merchants*, *Against Civil Servants*, *The Squaring of the Circle*, *The Merits of the Turks*, and, perhaps the most important, the *Book of Animals*.

The titles, however, give only a faint idea of their contents. Incapable of keeping to the point, al-Jahiz's essays wander from anecdote to anecdote, digression to digression, until both he and the reader lose sight of the original subject entirely.

Despite his propensity to meander in prose, al-Jahiz was particularly interested in style and correct expression. "The best style," he says in an essay on schoolteachers, "is the clearest, the style that needs no explication and no notes, that conforms to the subject expressed, neither exceeding it nor falling short."

This interest in style was characteristic of a group of Basran scholars, who, during the late eighth and early ninth centuries, sought to preserve the linguistic heritage of the Arabs by recording the poetry and sayings of the Bedouin of the Arabian peninsula. This movement had unanticipated results: because of their almost anthropological interest in the language and customs of the Bedouin, and in the social conditions of Arabia during both the pre-Islamic and Islamic periods, the Basran scholars achieved a deep appreciation of Arabic grammar and pre-Islamic poetry. They went on to compose sophisticated commentaries on the Koran, critical editions of poetry and treatises on grammar, and to compile dictionaries and specialized word-lists.

A master of these disciplines, al-Jahiz was one of the first writers of Arabic to work all the diverse preoccupations of the Basran scholarly milieu – grammar, prophetic tradition, rhetoric, lexicography and poetry – into a "literature" – that is, prose compositions to be read by non-specialists for pleasure and instruction.

Around the year 815, only two years after the founding of the House of Wisdom, al-Jahiz moved to Baghdad, where he was exposed to a new and important influence: Greek science, particularly Aristotelian thought. Attracted by scholastic theology, for instance, he subsequently used the dialectic method of the theologians in many of his works, often with humorous intent.

For al-Jahiz never lost sight of his readers, and developed a very personal and characteristic style, which blended anecdote, serious subjects and jokes, in an effort to hold their interest. He described his style himself, saying:

> My books contain above all unusual anecdotes, wise and beautifully expressed sayings handed down by the Companions of the Prophet, sayings which will lead to the acquisition of good qualities and the performance of good works …, they also contain stories of the conduct of kings and caliphs and their ministers and courtiers, and the most interesting events of their lives.

In Baghdad, al-Jahiz not only fused the Islamic sciences to Greek rationalism, but created Arabic prose literature. He showed that Arabic was flexible enough to handle any subject with ease, and although he was not personally associated with the House of Wisdom, his linguistic achievement paralleled – indeed surpassed – the efforts of the scholars engaged in rendering Greek scientific texts into Arabic.

His works attest the remarkable spread of Greek ideas among ordinary readers. Both in his subject matter and vocabulary, he presumes a familiarity – albeit superficial – with Aristotle and the technical terminology of scholastic theology. He tells many anecdotes of the scholars of the House of Wisdom, many of whom appear to have been his friends.

The book that best illustrates his method is his *Book of Animals – Kitab al-Hayawan* – which, even incomplete, runs to seven fat volumes in the printed edition.

Despite the title, the *Book of Animals* is by no means conventional zoology, or even a conventional bestiary. It is an enormous collection of lore about animals – including insects – culled from the Koran, the Traditions, pre-Islamic poetry, proverbs, storytellers, sailors, personal observation and Aristotle's *Generation of Animals*.

But this is by no means all. In keeping with his theories of planned disorder, he introduces anecdotes of famous men, snippets of history, anthropology, etymology and jokes. The bewildering variety of its contents, in fact, has always daunted translators, and later natural historians. Al-Damiri, who lived in the 14th century and wrote a well-known encyclopedia called *The Lives of the Animals*, used much of the scientific and linguistic information from al-Jahiz, but eliminated the anecdotes, poetry, digressions and jokes.

The "literary" quality of the *Book of Animals*, however, should not obscure the fact that it contains scientific information of great value. Anticipating a number of concepts which were not to be fully developed until the time of Darwin and his successors, al-Jahiz toys with evolutionary theory, discusses animal mimicry – noting that certain parasites adapt to the color of their host – and writes at length on the influences of climate and diet on men, plants and animals of different geographical regions. He even gets into animal communication, psychology and the degree of intelligence of insect and animal species. He gives a detailed account of the social organization of ants, including, from his own observation, a description of how they store grain in their nests in such a way that it does not spoil during the rainy season. He knows that some insects are responsive to light – and uses this information to suggest a clever way of ridding a room of mosquitoes and flies.

His greatest service, perhaps, was in popularizing science and the rational method, and in showing that a literary man could concern himself with any subject.

A devout Muslim, al-Jahiz regarded the physical world as the visible sign of God's will. His purpose in writing the *Book of Animals* was not merely to entertain, but to lead his readers to an appreciation of the wonders of God's creation, which he believed to be as manifest in the most insignificant as in the grandest:

> I would have you know that a pebble proves the existence of God just as much as a mountain, and the human body is evidence as strong as the universe that contains our world: for this purpose the small and slight carries as much weight as the great and vast.

Sadly, few works of al-Jahiz have survived the vicissitudes of time, but those that have make us regret all the more the ones that have been lost. Together they present a faithful and lively portrait of Baghdad and Basra during the Golden Age of Islam. He writes of singing girls, vagabonds, scholars, theologians, caliphs and viziers, and a very detailed picture of everyday life in

ninth-century Iraq could be extracted from his works. More importantly, he communicates to us the excitement of an intelligent non-specialist confronted with radical scientific, philosophical and theological speculations. Baghdad and Basra were awhirl with ideas, and al-Jahiz is very funny about the pretensions of people who studded their conversation with technical terms like "atom" without in the least understanding what an atom was.

At the same time, al-Jahiz enthusiastically supported certain aspects of the Greek tradition, by which he meant primarily Aristotle. He believed in the scientific method – as it was then understood – and applied reason and logic to observed phenomena. Loving a good story, however, al-Jahiz could never resist passing on the most preposterous yarns of sailors and Bedouin.

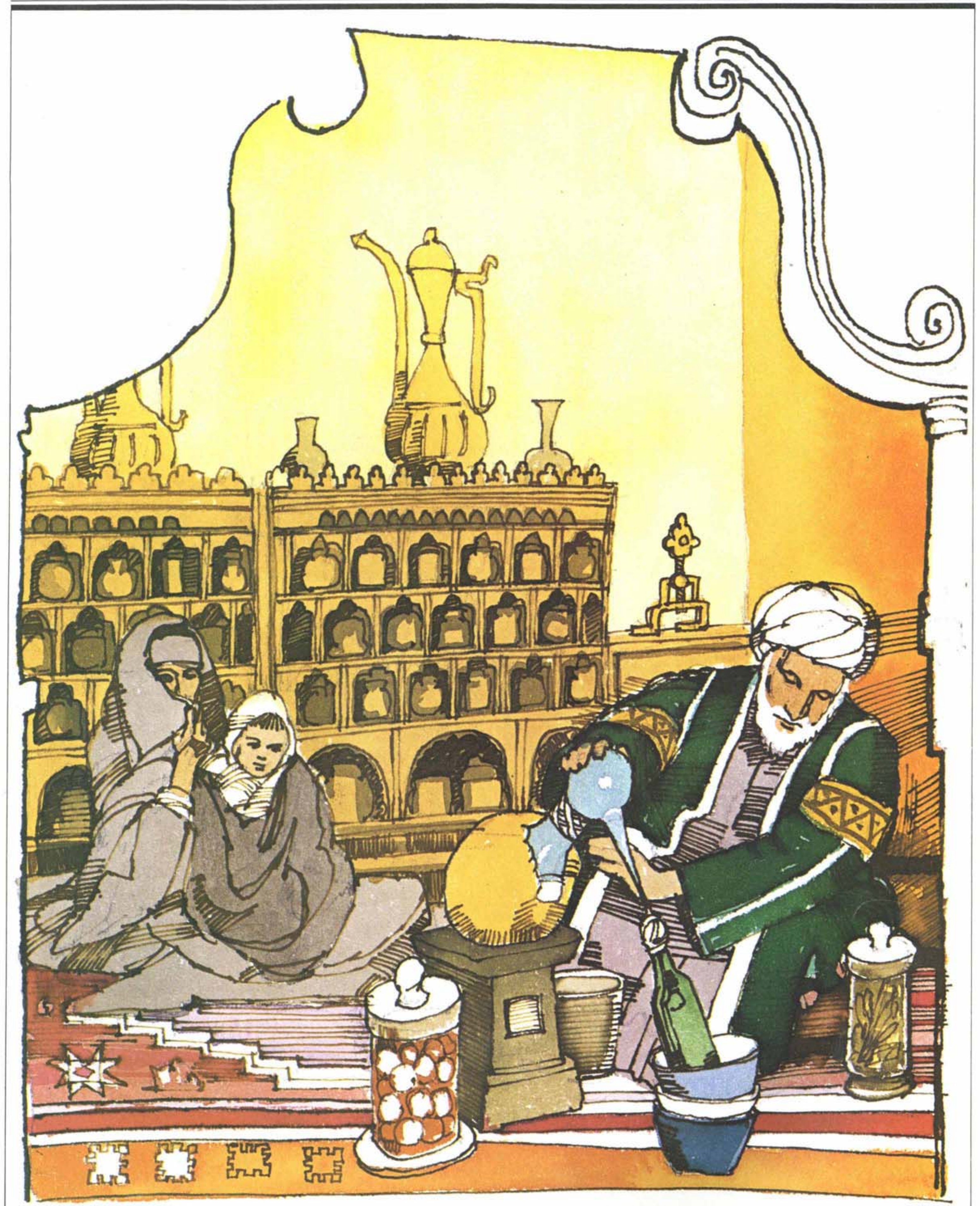
This lack of rational plan, so much a feature of his works, may have been at least partly deliberate, since his greatest fear was boring his readers. This does not mean that he was never serious, but that in all his major works, seriousness and humor are inextricably mixed; it is sometimes difficult to know when he is joking and when he is not. It is also difficult to pin al-Jahiz down on a given topic, for he loved to present debates between two social classes – scholars and merchants, mules and horses for instance – in which the merits of each are paraded before the reader. What the author himself thought is often not obvious, and it is possible that in these dialogues he was primarily interested in showing his skill at taking both sides of an argument.

He had a great love of books, and his *Book of Animals* begins with a long passage in their praise. It would have saddened him that so many of his own have perished, but he would have been delighted, one feels, with the manuscript from which the illustrations that adorn this article are taken.

This manuscript, which dates from the 14th century, was discovered in the Ambrosiana Library in Milan in 1939 by the Swedish scholar Oscar Löfgren. Löfgren stumbled on it, for it was not listed in the catalog of the manuscripts in the Ambrosiana done by von Hammer in 1839. He identified the text as a fragment of the *Book of Animals* – 87 folios containing about one-tenth of the complete text. The manuscript is not only fragmentary, but disordered. An ownership mark on the last folio states that when the fragment passed into the hands of a certain 'Abd al-Rahman al-Maghribi in 1615, it had 94 folios, so even at that date the manuscript was incomplete. It is not known how or when the Ambrosiana Library obtained the manuscript.

The Ambrosiana manuscript is textually very important. It is obviously copied by an educated scribe who has indicated the vowels – not normally written in Arabic – which allow the text to be more accurately understood than heretofore. This is doubly important as few manuscripts of the *Book of Animals* survive, and the Ambrosiana manuscript is among the earliest of those that do.

Even more important than the text, however, are the superb miniatures which illuminate it. Illustrated Arabic manuscripts of any sort are extremely rare, and this is the only illustrated copy of a work by al-Jahiz in existence. The 30 miniatures, done in a deliberately archaizing style – perhaps imitated from an earlier illustrated manuscript from al-Jahiz's native Iraq – were done at the high point of Arabic manuscript illumination: 14th-century Mamluk Egypt. A recent exhibition of Mamluk art at the Freer Gallery in Washington D.C. (see *Aramco World*, November-December 1981) has familiarized the American public with the glories of the Islamic decorative arts under the Mamluk dynasty. The style of the miniatures, consciously old-fashioned, succeeds in capturing the mood of al-Jahiz's prose – they are lively, highly colored and gently humorous. One cannot help feeling that al-Jahiz would have liked them, especially in view of his own admiration for the pictorial arts of the Byzantines and the Chinese – which he mentions in the *Book of Animals*. ■



SCIENCE IN AL-ANDALUS

WRITTEN BY PAUL LUNDE. PAINTINGS BY MICHAEL GRIMSDALE.
ILLUSTRATIONS COURTESY THE BODLEIAN LIBRARY. PHOTOGRAPH BY TOR EIGELAND

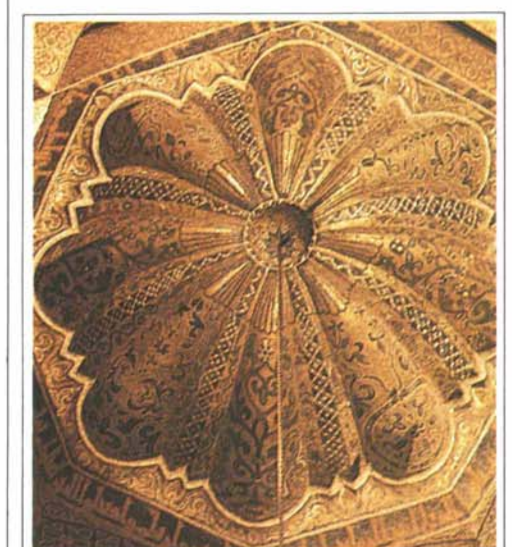
The medieval Christians of Spain had a legend that Roderick, the last King of the Visigoths, was responsible for unleashing the Arab invasion of the Iberian Peninsula because, in defiance of his plighted word, he unlocked the gates of an enchanted palace he had sworn not to tamper with.

As far as the West was concerned, the Arab invasion *did* unlock an enchanted palace. Following the collapse of the Roman Empire, Vandals, Huns and Visigoths had pillaged and burned their way through the Iberian Peninsula, establishing ephemeral kingdoms which lasted only as long as loot poured in, and were then destroyed in their turn. Then, without warning, in the year 711, came the Arabs – to settle, fall in love with the land and create the first civilization Europe had known since the Roman legions had given up the unequal fight against the barbarian hordes.

Spain first prospered under the rule of the Umayyads, who established a dynasty there after they had lost the caliphate in the east to the Abbasids. At first, the culture of the Umayyad court at Cordoba was wholly derivative. Fashions, both in literature and dress, were imitative of those current in the Abbasids' newly founded capital of Baghdad. Scholars from the more sophisticated lands to the east were always assured of a warm reception at the court of Cordoba, where their colleagues would listen avidly for news of what was being discussed in the capital, what people were wearing, what songs were being sung, and – above all – what books were being read.

For Islamic culture was pre-eminently a culture of the book. The introduction of paper from China in 751 gave an impetus to learning and an excitement for ideas which the world had never before known. Books became more available than they had been even in Rome, and incomparably cheaper than they were in the Latin West, where they continued to be written on expensive parchment. In the 12th century, a man sold 120 acres of land in order to buy a single Book of Hours. In the ninth century, the library of the monastery of St. Gall was the largest in Europe. It boasted 36 volumes. At the same time, that of Cordoba contained 500,000. The cultural lag between East and West in the Middle Ages can be attributed partly to the fact that the Arabs had paper, while the Latin West did not.

It took much more than paper to create an intellectual and scientific culture like



that of Islamic Spain, of course. Islam, with its tolerance and encouragement of both secular and religious learning, created the necessary climate for the exchange of ideas. The court of Cordoba, like that of Baghdad, was open to Muslims, Jews and Christians alike, and one prominent bishop complained that young Christian men were devoting themselves to the study of Arabic, rather than to Latin – a reflection of the fact that Arabic, in a surprisingly short time, had become the international language of science, as English has today.

Islamic culture in Spain began to flourish in earnest during the reign of 'Abd al-Rahman II of Cordoba – as Arabic spread increasingly among his non-Muslim subjects, especially in the cities, and led to a great flowering of intellectual activity of all kinds.

In a courtly society, the tastes and predilections of the ruler set the tone for society at large, and 'Abd al-Rahman II, passionately interested in both the religious and the secular sciences, was determined to show the world that his court was in no way inferior to the court of the Caliphs at Baghdad. To this end, therefore, he actively recruited scholars by offering handsome inducements to overcome their initial reluctance to live in what many from the lands in the East considered the provinces. As a result, many scholars, poets, philosophers, historians and musicians migrated to al-Andalus, and established the basis of the intellectual tradition and educational system which made Spain so outstanding for the next 400 years.

Another result was that an infrastructure of libraries – both public and private – mosques, hospitals, and research institutions rapidly grew up and famous scholars in the East, hearing of these amenities, flocked to the West. They in turn attracted students of their own; in the Islamic world it was not at all unusual for a student to travel thousands of miles to study at the feet of a famous professor.

Science : The Islamic Legacy

One of the earliest of these scholars was 'Abbas ibn Firnas, who died in the year A.D. 888 and who, had he lived in the Florence of the Medici, would have been a "Renaissance Man." He came to Cordoba to teach music, then a branch of mathematical theory, but – not a man to limit himself to a single field of study – soon became interested in the mechanics of flight. He constructed a pair of wings, made out of feathers in a wooden frame, and attempted to fly – anticipating Leonardo da Vinci by some 600 years.

Luckily, 'Abbas survived, and, undiscouraged, turned his mind to the construction of a planetarium in which the planets actually revolved – it would be extremely interesting to know the details of the gearing mechanism. It also simulated such celestial phenomena as thunder and lightning and was, of course, a wild success. Next 'Abbas turned to the mathematical problems involved in the regularity of the facets of certain crystals and evolved a formula for manufacturing artificial crystals.

It must be remembered that a knowledge of the achievements of men like 'Abbas has come to us purely by chance. It has been estimated that today there are 250,000 Arabic manuscripts in Western and Eastern libraries, including private collections. Yet in the 10th century, private libraries existed which contained as many as 500,000 books. Literally millions of books must have perished, and with them the achievements of a great many scholars and scientists, whose books, had they survived, might have changed the course of history. As it is, even now, only a tiny proportion of existing Arabic scientific texts have been studied, and it will take years to form a more exact idea of the contributions of Muslim scientists to the history of ideas.

One of the fields most assiduously cultivated in Spain was natural science. Although Andalusian scholars did not make contributions as fundamental as those made by their colleagues in the East, those that they did make had more effect on the later development of science and technology, for it was through Spain and the scholars of al-Andalus that these ideas reached the West.

No school of translators comparable to the House of Wisdom of al-Ma'mun existed in Spain, and Andalusian scholars seem not to have interested themselves in the natural sciences until the translations of the House of Wisdom reached them.

Interest in mathematics, astronomy, and medicine was always lively, because of their obvious utility – mathematics for commercial purposes, computation of the rather complicated Islamic laws of inheritance, and as a basis for measuring distances. Astronomy was useful for determining the times of prayer and adjusting the calendar, and the study of medicine needed no apology. The introduction of the new Aristotelian ideas, however, even in Arab dress, aroused a certain amount of suspicion in the conservative West, and it was some time before public opinion would accept that Aristotelian logic did not conflict with the Revelation.

Part of the suspicion with which certain of the ideas emanating from the scholars of the Abbasid court were viewed was due to an inadequate distinction between sciences and pseudo-sciences. This was a distinction which the Muslims made at a much earlier date than Western scholars, who, even during the Renaissance, tended to confound astronomy with astrology, chemistry with alchemy. Ibn Hazm, a leading Andalusian scholar of the 11th century and staunchly conservative, was very outspoken on this point. People who advocated the efficacy of talismans, magic, alchemy, and astrology he calls shameless liars. This rational approach did much to make Islam preeminent in the natural sciences.

The study of mathematics and astronomy went hand in hand. Al-Khwarizmi's famous book entitled *The Calculation of Integration and Equation* reached al-Andalus at an early date, and became the foundation of much later speculation. In it, Al-Khwarizmi dealt with equations, algebraic multiplication and division, measurement of surfaces, and other questions. Al-Khwarizmi was the first to introduce the use of what he called "Indian" and what we call "Arabic" numerals. The exact method of the transmission of these numerals – and the place-value idea which they embodied – is not known, but the symbols used to represent the numbers had slightly different forms in Eastern and Western Islam, and the forms of our numerals are derived from those used in al-Andalus. The work of al-Khwarizmi, which now only survives in a 12th century Latin translation made in Spain, together with a translation of Euclid's *Elements,* became the two foundations of subsequent mathematical developments in al-Andalus.

The first original mathematician and astronomer of al-Andalus was the 10th century's Maslama al-Majriti. He had been preceded by competent scientists – men like Ibn Abi 'Ubaida of Valencia, who in the ninth century was a leading astronomer – and the *emigré* from Baghdad, Ibn Taimiyyah, who was both a well-known physician and an astronomer, but al-Majriti was in a class by himself. He wrote a number of works on mathematics and astronomy, studied and elaborated the Arabic translation of Ptolemy's *Almagest* and enlarged and corrected the astronomical tables of al-Khwarizmi himself. He compiled conversion tables, in which the dates of the Persian calendar were related to *Hijra* dates, so that for the first time the events of Persia's past could be dated with precision.

Al-Zarqali, known to the Latin West as Arzachel, was another leading mathematician and astronomer who flourished in Cordoba in the 11th century. He combined theoretical knowledge with technical skill, and excelled at the construction of precision instruments for astronomical use. He built a waterclock capable of determining the hours of the day and night and indicating the days of the lunar month. He contributed to the compilation of the famous *Toledan Tables,* a highly accurate compilation of astronomical data. His *Book of Tables,* written in the form of an almanac (almanac is an Arabic word meaning climate, originally indicating the stations of the moon) contains tables which allow one to find on what day the Coptic, Roman, lunar and Persian months begin; others give the position of the various planets at any given time; and still others allow prediction of solar and lunar eclipses. He also compiled valuable tables of latitude and longitude; many of his works were translated, both into Spanish and into Latin.

Still another luminary was al-Bitruji (the Latin scholars of the middle ages called him Alpetragius), who developed a new theory of stellar movement and wrote the *Book of Form* in which it is detailed.

The influence of these astronomical works was immense. Today, for example, the very appelations of the constellations still bear the names given them by Muslim astronomers – Acrab (from *'aqrab,* "scorpion"), Altair (from *al-ta'ir,* "the flyer"), Deneb (from *dhanb,* "tail"), Pherkard (from *farqad,* "calf") – and words such as zenith nadir and azimuth, all still in use today, recall the works of the Muslim scholars of al-Andalus.

But the Muslim science *par excellence* was the study of medicine. Interest in medicine goes back to the very earliest times. The Prophet himself stated that there was a remedy for every illness, and was aware that some diseases were contagious.

The great contribution of the Arabs was to put the study of medicine on a scientific footing, and eliminate superstition and harmful folk-practices. Medicine was considered a highly technical calling, and one which required long study and training. Elaborate codes were formulated to regulate the professional conduct of doctors. It was not enough to have a mastery of one's subject in order to practice medicine. Certain moral qualities were mandatory. Ibn Hazm said that a doctor should be kind, understanding, friendly, good, able to endure insults and adverse criticism; he must keep his hair short, and his fingernails as well; he must wear clean, white clothes, and behave with dignity.

Before doctors could practice, they had to pass an examination, and if they passed they had to take the Hippocratic oath, which, if neglected, could lead to dismissal.

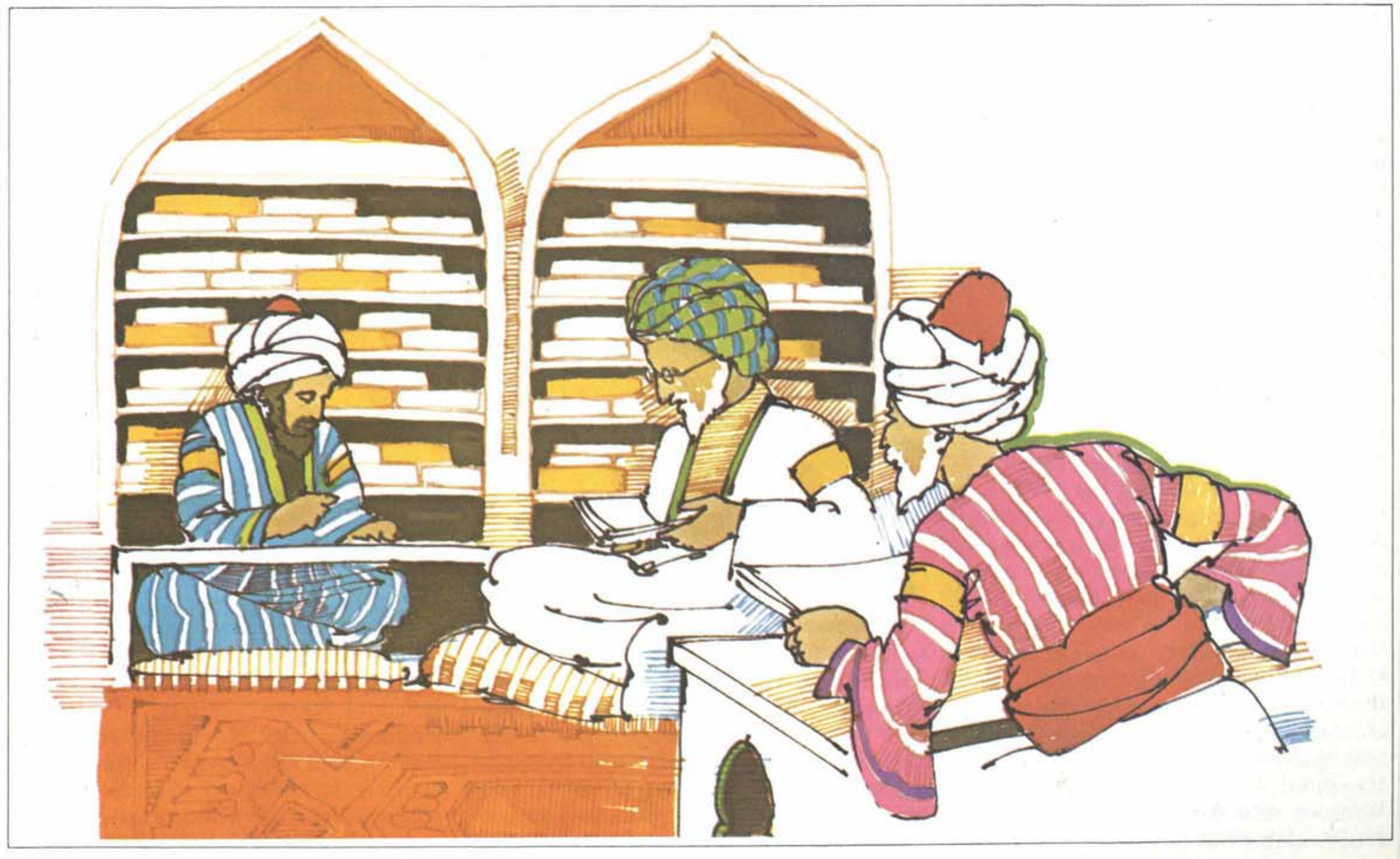
Hospitals were similarly organized. The large one built in Cordoba was provided with running water and baths, had different sections for the treatment of various diseases, each section of which was headed by a specialist. Hospitals were required to be open 24 hours a day to handle emergency cases, and could not turn any patient away.

Muslim physicians made many important additions to the body of medical knowledge which they inherited from the Greeks. Ibn al-Nafis, for example, discovered the lesser circulation of the blood hundreds of years before Harvey and ideas of quarantine sprang from an empirical notion of contagion.

Another example is Ibn Juljul who was born in Cordoba in 943, became a leading physician by the age of 24 (he began his studies of medicine at the age of 14) and compiled a commentary on the *De Materia Medica* of Dioscorides, and a special treatise on drugs found in al-Andalus. In his *Categories of Physicians,* composed at the request of one of the Umayyad princes, he also presents a history of the medical profession from the time of Aesculapius to his own day.

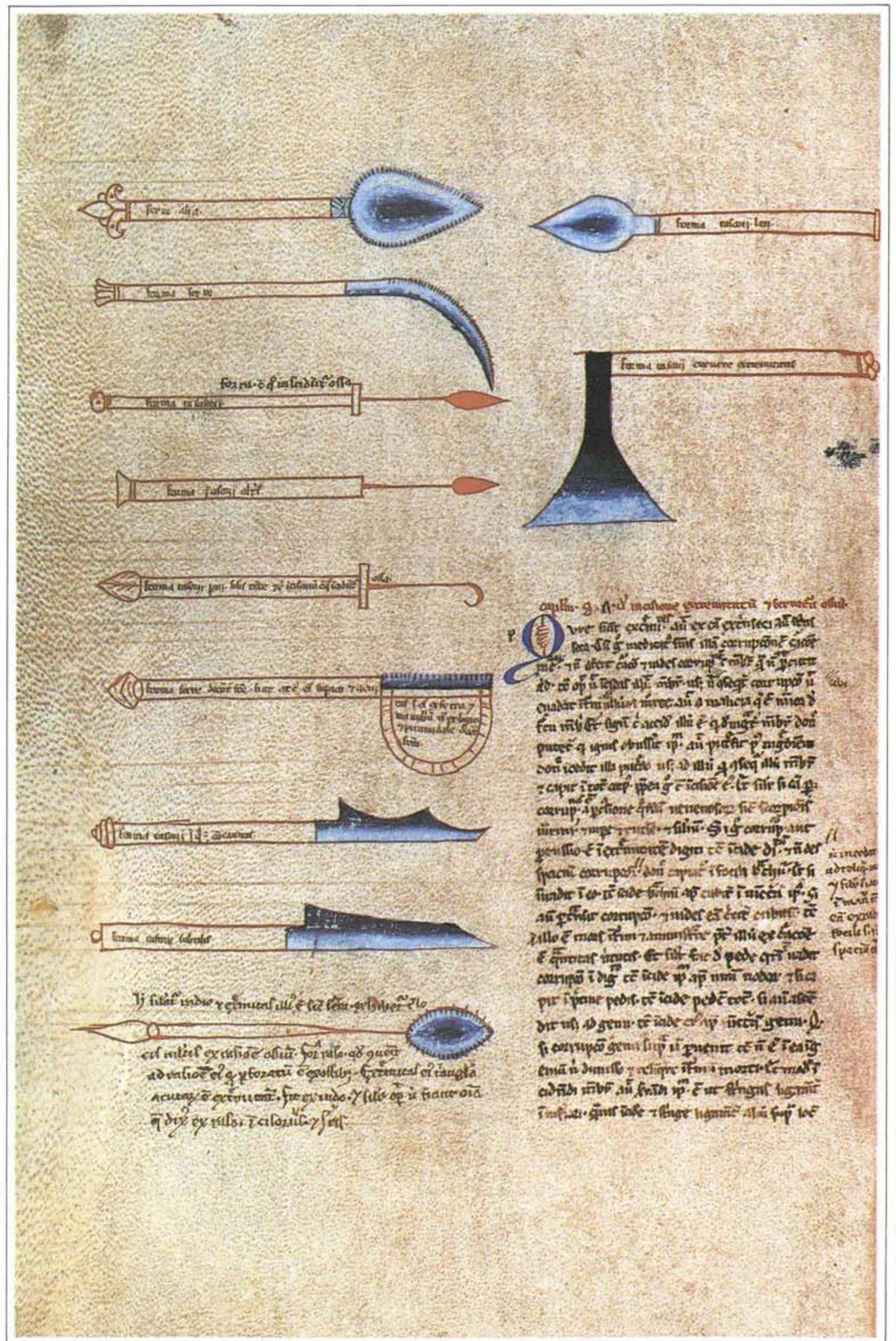
During the 10th century, al-Andalus produced a large number of excellent physicians. Several went to Baghdad, where they studied Greek medical works under the famous translators Thabit Ibn Qurra and Thabit ibn Sinan. On their return, they were lodged in the government complex at Madinat al-Zahra. One of these men, Ahmad ibn Harran, was placed in charge of a dispensary which provided free medical care and food to poor patients.

Ibn Shuhaid, also known as a popular doctor, wrote a fundamental work on the use of drugs. He – like many of his contemporaries – recommended drugs only if the patient did not respond to diet, and said that if they must be used, simple drugs should be employed in all cases but the most serious.



Al-Zahrawi, who died in 1013, was the most famous surgeon of the Middle Ages. He was court physician of al-Hakam II, and his great work, the *Tasrif,* was translated into Latin by Gerard of Cremona and became a leading medical text in European universities in the later middle ages. The section on surgery contains a number of illustrations of surgical instruments of elegant, functional design and great precision. It describes lithotrites, amputations, ophthalmic and dental surgery, the treatment of wounds and fractures.

Ibn Zuhr, known as Avenzoar who died in 1162, was born in Seville and earned a great reputation throughout North Africa and Spain. He described abscesses and mediastinal tumors for the first time, and made original experiments in therapeutics. One of his works, the *Taysir,* was translated into Latin in 1280 and became a standard work.



An outgrowth of the interest in medicine was the study of botany. The most famous Andalusian botanist was Ibn Baitar, who wrote a famous book called *Collection of Simple Drugs and Food.* It is an alphabetically arranged compendium of medicinal plants of all sorts, most of which were native to Spain and North Africa, which he spent a lifetime gathering. Where possible, he gives the Berber, Arabic, and sometimes Romance names of the plant, so that for linguists his work is of special interest. In each article, he gives information about the preparation of the drug and its administration, purpose and dosage.

The last of the great Andalusian physicians was Ibn al-Khatib, who was also a noted historian, poet, and statesman. Among his other works, he wrote an important work on the theory of contagion: "The fact of infection becomes clear to the investigator who notices how he who establishes contact with the afflicted gets the disease, whereas he who is not in contact remains safe, and how transmitting is effected through garments, vessels, and earrings."

Ibn al-Khatib was the last representative of the Andalusian medical tradition. Soon after his death, the energies of the Muslims of al-Andalus were wholly absorbed in the long costly struggle against the Christian *reconquista.*

Another field that interested the scholars of al-Andalus was the study of geography and many of the finest Muslim works in this field were produced there. Economic and political considerations played some part in the development of the study of geography, but it was above all their all-consuming curiosity about the world and its inhabitants that motivated the scholars who devoted themselves to the description of the earth and its inhabitants. The first steps had been taken in the east, when "Books of Routes," as they were called, were compiled for the use of the postmasters of the early 'Abbasid Caliphs. Soon, reports on far away lands, their commercial products and major physical features were compiled for the information of the Caliph and his ministers. Advances in astronomy and mathematics made the plotting of this information on maps feasible, and soon cartography had become an important discipline in its own right.

Al-Khwarizmi, who did so much to advance the science of mathematics, was also one of the earliest scientific descriptive geographers. Basing his work on information made available through the Arabic translation of Ptolemy, al-Khwarizmi wrote a book called *The Form of the Earth,* which included maps of the heavens and of the earth. In al-Andalus, this work was carried forward by Ibn Muhammad al-Razi – Rhazes – who died in 936, and who wrote a basic geography of al-Andalus for administrative purposes. Muhammad ibn Yusuf al-Warraq, a contemporary of al-Razi, wrote a similar work describing the topography of North Africa. The wide-ranging commercial relations of al-Andalus allowed the collection, from returning merchants, of a great deal of detailed information about regions as far north as the Baltic. Ibrahim ibn Ya'qub, for example, who travelled widely in Europe and the Balkans in the late ninth century – he must have been a brave man indeed – left itineraries of his travels.

Two men who wrote in the 11th century collected much of the information assembled by their predecessors, and put it into convenient form. One of them, al-Bakri, is particularly interesting. Born in Saltes in 1014, al-Bakri was the son of the governor of the province of Huelva and Saltes. Al-Bakri himself was an important minister at the court in Seville, and undertook several diplomatic missions. An accomplished scholar, as well as *litérateur,* he wrote works on history, botany and geography as well as poetry and literary essays. One of his two important geographical works is devoted to the geography of the Arabian Peninsula with particular attention to the elucidation of its place names. It is arranged alphabetically, and lists the names of villages, towns, wadis, and monuments which he culled from the *hadith* and histories. His other major work has not survived in its entirety, but it was an encyclopedic treatment of the entire world.

Al-Bakri arranged his material by country – preceding each entry by a short historical introduction – and describes the people, customs, climate, geographical features and the major cities – with anecdotes about them. He says of the inhabitants of Galicia, for example: "they are treacherous, dirty, and bathe once or twice a year, even then with cold water; they never wash their clothes until they are worn out because they claim that the dirt accumulated as the result of their sweat softens their body."

Perhaps the most famous geographer of the time was al-Idrisi, "the Strabo of the Arabs." Born in 1100 and educated in Cordoba, al-Idrisi travelled widely, visiting Spain, North Africa, and Anatolia, until he eventually settled in Sicily, where he was employed by the Norman King, Roger II, to write a systematic geography of the world, which is still extant, and is usually known as *The Book of Roger.*

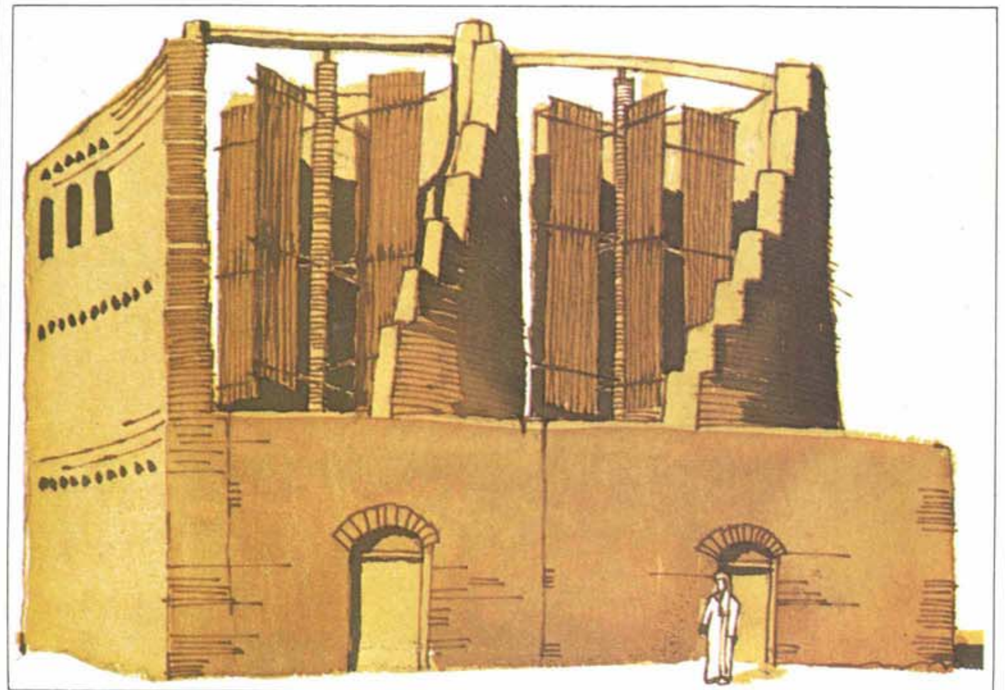
In it, al-Idrisi describes the world systematically, following the Greek division of it into seven "climes", each divided into 10 sections. Each of the climes is mapped – and the maps are highly accurate for the time in which they were compiled. He gives the distances between major cities, describes the customs, people, products, and climate of the entire known world. He even records the voyage of a Moroccan navigator who was blown off course in the Atlantic, sailed for 30 days, and returned to tell of a fertile land inhabited by naked savages. America?

The information contained in *The Book of Roger* was engraved on a silver planisphere, which was one of the wonders of the age.

Al-Andalus also produced the authors of two of the most interesting travel books ever written. Both exist in good English translation. The first is by Ibn Jubair, secretary to the Governor of Granada who, in 1183, made the Hajj, and wrote a book about his journey, called simply *Travels.* The book is in the form of a diary, and gives a detailed account of the eastern Mediterranean world at the height of the Crusades. It is written in clear elegant style, and is filled with the perceptive intelligent comments of a tolerant – and often witty – man.

The most famous of all the Andalusian travellers was Ibn Battuta – the greatest tourist of his age – and perhaps of any. He went to North Africa, Syria, Makkah, Medina and Iraq. He went to Yemen, sailed down the Nile, the Red Sea, Asia Minor, and the Black Sea. He went to the Crimea and to Constantinople. He went to Afghanistan, India and China. He died in Granada at the age of 73.

It is impossible to do justice to all the scholars of al-Andalus who devoted themselves to the study of history and linguistic sciences. Both were the prime "social sciences" cultivated by the Arabs, and both were brought to a high level of art in



al-Andalus. For example, Ibn al-Khatib, whose theory of contagious diseases we have touched on already, was the author of the finest history of Granada that has come down to us.

Ibn al-Khatib was born in 1313, near Granada, and followed the traditional educational curriculum of his time – he studied grammar, poetry, natural sciences, and Islamic law, as well, of course, as the Koran. His father, an important official, was killed by the Christians in 1340. The ruler of Granada invited his son to occupy the post of secretary in the Department of Correspondence. He soon became the confidant of the ruler, and gained a position of great power.

Despite his busy political career, Ibn al-Khatib found time to write more than 50 books on travel, medicines, poetry, music, history, politics and theology.

The achievements of Ibn al-Khatib were rivalled only by those of his near contemporary, Ibn Khaldun, the first historian to seek to develop and explicate the general laws which govern the rise and decline of civilizations. His huge, seven volume history is entitled *The Book of Examples and Collections from Early and Later Information Concerning the Days of Arabs, Non-Arabs and Berbers.* The first volume, entitled *Introduction* gives a profound and detailed analysis of Islamic Society and indeed, of human society in general, for he constantly refers to other cultures for comparative purposes. He gives a sophisticated analysis of how human society evolved from nomadism to urban centers, and how and why these urban centers decay, and finally succumb to less developed invaders. Many of the profoundly disturbing questions raised by Ibn Khaldun have still not received the attention they should from all thinking men. Certainly, anyone interested in the problems of the rise and fall of civilizations, the decay of cities, the complex relationship between technologically advanced societies and traditional ones should read Ibn Khaldun's *Introduction to History* .

Another great area of Andalusian intellectual activity was philosophy but it is impossible to do more than glance at this difficult and specialized study. From the ninth century, Andalusian scholars, like those in Baghdad, had to deal with the theological problems posed by the introduction of Greek philosophy into a context of Islam. How could reason be reconciled with Revelation? This was the central question.

Ibn Hazm was one of the first to deal with this problem. He supported certain Aristotelian concepts with enthusiasm and rejected others. For example he wrote a large and detailed commentary on Aristotle's *Posterior Analects,* that abstruse work on logic. Interestingly, Ibn Hazm appears to have had no trouble relating logic to Islam – in fact, he gives illustrative examples of how it can be used in solving legal problems drawn from the *Shari'ah.* Nothing illustrates the ability of Islam to assimilate foreign ideas and acclimatize them better than Ibn Hazm's words in the introduction to his work: "Let it be known that he who reads this book of ours will find that the usefulness of this kind of work is not limited to one single discipline but includes the Koran, *hadith,* and legal decisions concerning what is permissible and what is not, and what is obligatory and what is lawful."

Ibn Hazm considered logic a useful tool, and philosophy to be in harmony, or at least not in conflict, with Revelation. He has been described as "one of the giants of the intellectual history of Islam," but it is difficult to form a considered judgment of a man who wrote more than 400 books, most of which have perished or still remain in manuscript.

Ibn Bajjah, whom western scholastic theologians called Avempace, was another great Andalusian philosopher. But it was Averroes – Ibn Rushd – who earned the greatest reputation. He was an ardent Aristotelian, and his works had a lasting effect, in their Latin translation, on the development of European philosophy.

Islamic technological innovations also played their part in the legacy of al-Andalus to medieval Europe. Paper has been mentioned, but there were others of great importance – the windmill, new techniques of working metal, making ceramics, building, weaving and agriculture. The people of al-Andalus had a passion for gardens, combining their love of beauty with their interest in medicinal plants. Two important treatises on agriculture – one of which was partially translated into Romance in the Middle Ages, were written in al-Andalus. Ibn al-'Awwam, the author of one of these treatises, lists 584 species of plants and gives precise instructions regarding their cultivation and use. He writes, for example, of how to graft trees, make hybrids, stop blights and insect pests and how to make floral essences and perfumes.

This area of technological achievement has not yet been examined in detail, but it had as profound an influence on medieval European material culture as the Muslim commentators on Aristotle had on medieval European intellectuals. For these were the arts of civilization, the arts that make life a pleasure rather than a burden, and without which philosophical speculation is an arid exercise. ■

THE BODLEIAN REMEMBERS

WRITTEN BY CHARIS WADDY
ILLUSTRATIONS COURTESY THE BODLEIAN LIBRARY, OXFORD UNIVERSITY

Last year, to mark the opening of the 15th Islamic century, Oxford University's Bodleian Library scanned its collection of Arabic manuscripts – one of the world's largest – and mounted a display of 50 choice works to tell one of the great stories in the history of ideas: the flowering of philosophy and science in the medieval Muslim world and the transmission of that tradition – the *doctrina Arabum,* the teachings of the Arabs – to Europe.

With the influence of Islam again spreading and growing, and its intellectual traditions being revived, 1981 – which is 1401 on the Muslim calendar – was an especially appropriate year to open the Bodleian display. As Colin Wakefield, curator of the collection and organizer of the exhibit, said at the opening, "... the exhibition ... by focusing attention on the debt of medieval Europe to the scholars of the Muslim world, may shed an interesting sidelight on the long and turbulent history of relations between Islam and the West."

To display its Arabic treasures, Bodleian experts chose Oxford's Divinity School, built 500 years ago for the teaching of theology, then "queen of sciences." A splendid example of craftsmanship in the final flowering of the Gothic age, the Divinity School and the library above it – built by Duke Humfrey of Gloucester, brother to King Henry V – were a part of the outburst of building that occurred after the years of conflict with France and the civil strife known as the Wars of the Roses; this period produced the perpendicular Gothic unique to England and such structures as the new "College of All Souls of the Faithful Departed," a war memorial to those killed in the Hundred Years War, and, not far away, the Bell Tower of Magdalen College.

Today, beneath the richly carved, vaulted stone roof of the Divinity School, the surrounding library stores some of its greatest documents and manuscripts: the first folio edition of Shakespeare, one of the original copies of the Magna Carta and handwritten poems and letters by Shelley, Browning and Byron. In 1981, the library also displayed the 50 works which trace the

transmission of science and philosophy from the classical world to Europe along a route which ran eastwards through Byzantium to Baghdad, then, via Sicily and Spain, northwards to the centers of Europe at the very moment when hungry minds were eager for the food that centuries of Muslim civilization had to offer.

The manuscripts evoke two major periods of intense intellectual activity: Baghdad in the days of the early Abbasid caliphs – the ninth and 10th centuries of the Christian era – and the quickening of thought in 12th- and 13th-century Europe. Both these periods saw the indefatigable work of translators: first those who brought the corpus of classical knowledge to the Arabs and, 300 years later, those who passed it on to Western Europe enriched by the labors of Muslim scholars. It is this story that was the focus of the exhibit.

Take Aristotle, for instance. Only a fraction of his work was known in Europe during the post-classical era, when barbarian invasions caused the loss of so much earlier culture. But most of his books were translated into Arabic, and were studied and commented on over and over again in Baghdad and other centers. European philosophers rediscovered them via these commentaries. Ibn Sina (Avicenna) and Ibn Rushd (Averroes) were famous names in medieval philosophy, and their predecessor al-Farabi (Alfarabius) is said to have lectured on Aristotle's *Physics* 40 times and his *Rhetoric* 80 times.

At the Bodleian exhibit, the scope of the scientific tradition which reached Europe was shown in the headings of the exhibition: medicine. biology, alchemy and magic; astronomy and astrology; mathematics and optics. It was especially rich in the fields of medicine, mathematics and the early experiments in alchemy – which were to lead to the development of modern chemistry – for while 13th century Paris excelled in philosophy, Oxford was ahead in science. Roger Bacon, for example, who is credited with initiating the first developments in experimental science, was represented in the exhibition by his *Opus Tertius;* the third part of an encyclopedic work, it cites all the above named philosophers, as well as the astronomer al-Zarqali, and Ibn al-Haitham, whose works on optics had a great influence on early European scientists – and whose own works were also in the exhibition.

It is notable that many of the Latin manuscripts shown date from the 13th and 14th centuries – examples of the textbooks used in teaching and research in the universities of that period. They were housed in college libraries such as that of Merton College – which produced a sequence of brilliant mathematicians in pre-Renaissance times – or in the first library belonging to the university, a small building adjoining the University Church.

The main center of Latin translations from Arabic was Toledo, reconquered from the Arabs in 1085 and for 200 years a center in which Latin, Greek and Arabic were all in use. Another center was Sicily, where the Norman kings gathered a brilliant, multi-lingual court, which, at the Bodleian, was represented by a translation of a manuscript made for the Emperor Frederick II, who not only encouraged learning of all sorts but also kept a zoo, wrote on falconry, and was passionately interested in animals. The manuscript contains the zoological chapters of an Arabic encyclopedia, a famous work by Ibn Sina, *al-Shifa* — other portions of which were also displayed – dealing with physics and with the existence of the soul.

The zoological section of this encyclopedia was translated by Michael Scott, a contemporary of Roger Bacon. Scott, whose studies in astrology gave him a sinister reputation as a magician, was probably from Scotland, and traveled south in search of the new learning. As was the custom then, the equivalent of today's doctoral candidate would make his way, on foot, to Spain, and perhaps Sicily as well, to hear "the wisest philosophers in the world," and return bringing some fresh work which scientists at home – Bacon and others – would incorporate in their teaching and research. Scott worked as a translator in Toledo for some years, then went to Sicily, where he was appointed Court Astrologer to Frederick II. No doubt he took with him the translation he had already made of Aristotle's writings on animals, for an interest in the animal world would find favor with the emperor.

Botany and agriculture follow zoology, and anthropologists undoubtedly took special note of Ibn Wahshiyya's *al-Filaha al-Nabatiyya,* a treatise on farming which gives a wealth of facts about popular customs, religion and magic as well as agricultural and botanical information. Another vital work, basic to the study of pharmacology, is the *De Materia Medica* by Dioscorides, a Greek writer of the first century. It led to the science in which the Muslims excelled: medicine.

In the history of medicine, a number of books from Arab sources became standard texts reproduced first in manuscript and later in print. Works by the fathers of Greek medicine, Hippocrates and Galen, for example, were known to the Arabs and translated into Arabic during the eighth and ninth centuries. Under the caliph al-Ma'mun, son of Harun al-Rashid, a translation center in Baghdad, known as *Bait al-Hikma,* the House of Wisdom, was established, at which the outstanding Hunain ibn Ishaq is said to have translated 100 books by Galen, Hippocrates and other physicians. Later, Hunain's own authoritative *Introduction to Medicine* was translated into Latin – and remained a popular manual of instruction for 600 years. His only rival was Gerard of Cremona, the greatest translator of the Toledo school. When he died, his pupils drew up a list of 71 of his translations – and it was not exhaustive. One of his greatest contributions, a version of Avicenna's *Canon of Medicine* (Ibn Sina's *al-Qanun fi al-Tibb*), was used in both Europe and the Islamic world from the 11th to the 17th centuries and, during the 15th and 16th centuries, was printed at least 35 times in Europe.

Another of Gerard's translations was of a book on surgery, by al-Zahrawi, who practiced medicine in al-Andalus in the 11th century. The various Latin printed editions of his work include one published in Oxford in 1778. Diagrams of surgical instruments found in the Arabic manuscript are copied in the translation.

Alongside these major texts was shown a smaller one, a traveler's manual with medical advice by a North African doctor who died about 1004. This manual was popular in the Muslim world, and it became equally so in Europe when one of the first medical translators, Constantinus Africanus, produced a Latin version – which he claimed as his own work.

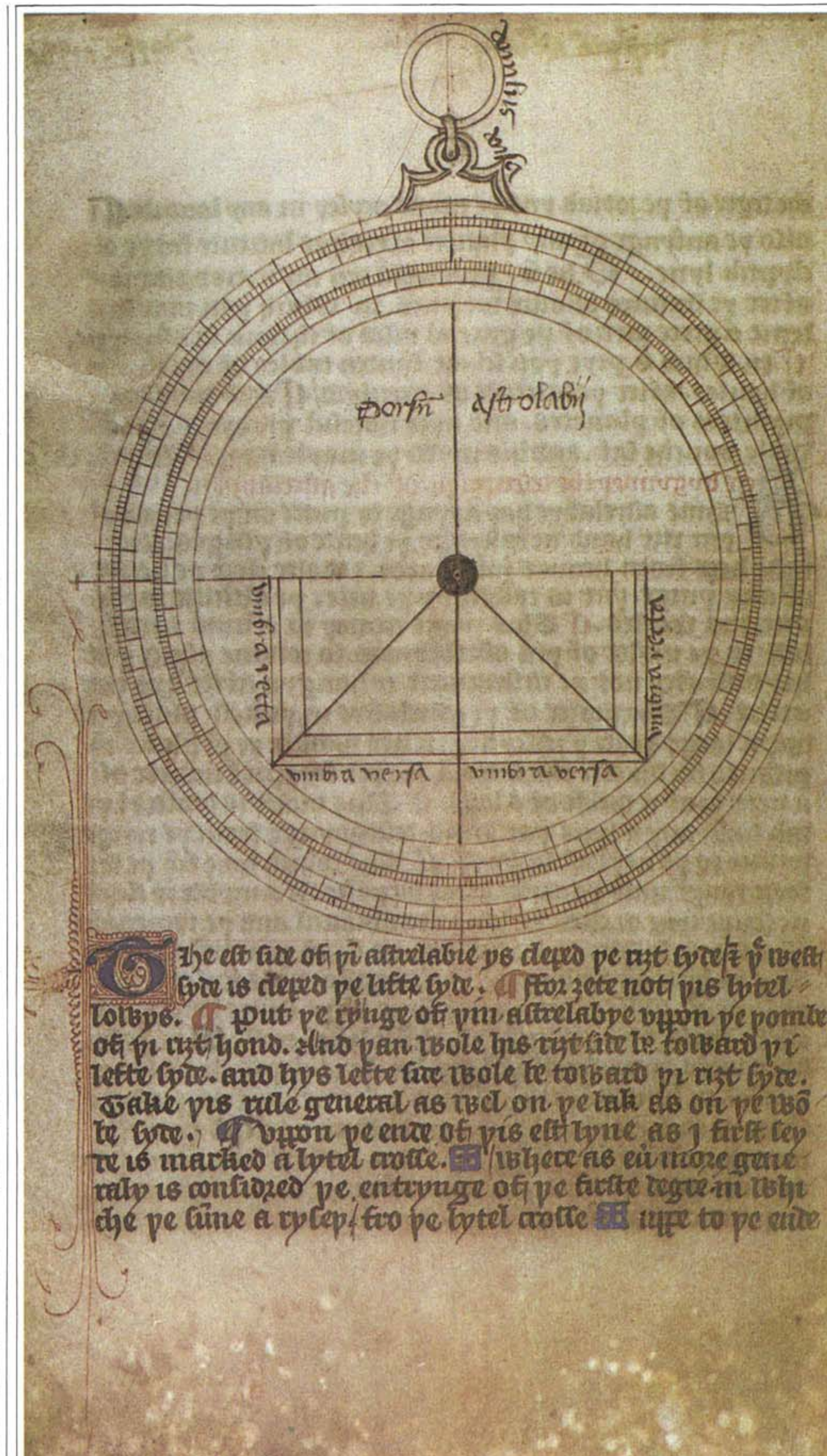
One other name that must not be omitted is that of Maimonides, the Jewish scholar, philosopher and physician who left Cordoba for Egypt and practiced medicine in Cairo in the time of Salah al-Din (Saladin). One of his numerous medical works was a regimen of health prepared for the son of Saladin, who succeeded his father as ruler of Egypt. Also shown is Maimonides' *Guide to the Perplexed,* composed, as was customary for Jewish authors at the time, in Arabic, but written in the Hebrew alphabet.

Moving on to astronomy and mathematics, the exhibit showed the debt of European astronomers to their Eastern counterparts for the foundations on which all subsequent advances in scientific study were to be built. Included, for example, was the mathematician al-Khwarizmi, who worked in Baghdad and drew up some of the earliest astronomical tables used by the Arabs. Revised in Cordoba, these tables were translated by Adelard of Bath, whose Latin version was used by many early European astronomers.

In another book, also shown in the exhibition, the same al-Khwarizmi introduces algebra to Europe. But his most important contribution was the introduction – via Baghdad – of the Indian system of numerals, which, in the 13th century, began to replace the cumbersome Latin system of numeration. Renamed "Arabic numerals," they spread from the merchants of the Mediterranean ports into every sphere of life.

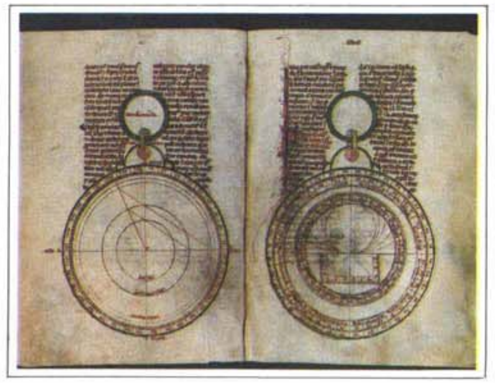
Geometry was also represented at the Bodleian exhibition – in one of the great classical works: the *Conics* of Apollonius of Perga. It consisted of seven books, three of which survive *only* in Arabic translation. The Oxford astronomer Edmund Halley – famous for his observation of the comet known by his name – used Bodley's Arabic manuscript of the *Conics* in preparing a complete edition of that work, published in 1710.

Other Oxford astronomers in the 17th century also drew on Muslim sources – such as the star tables worked out in the magnificent observatory in Samarkand, built in the 15th century by Ulugh Beg, a grandson of Tamerlane. These astronomi-



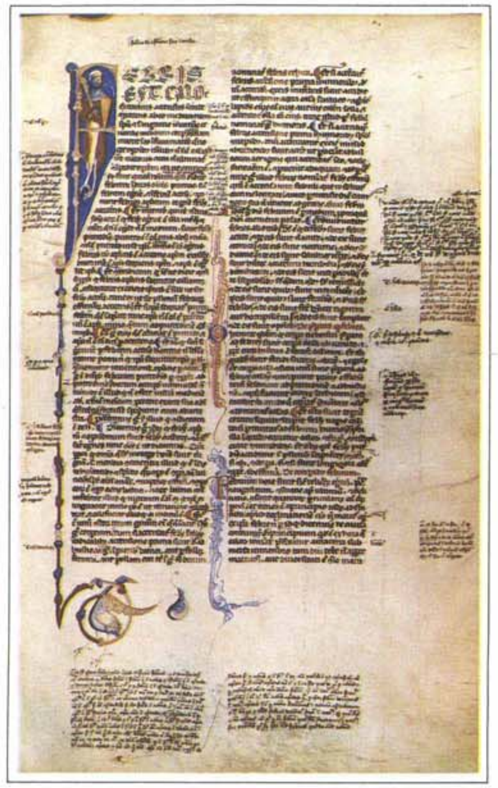
cal and chronological tables were an advance on those of previous scientists. They became known in Europe in the 17th century, and the Savilian Professor of Astronomy, John Greaves, obtained and used the manuscript exhibited here, in preparing the tables for publication with a Latin translation: a continuation five centuries later of the 12th-century practice.

Finally, two manuscripts deal with the making of scientific instruments – another field in which much was owed to Islamic sources. One of the earliest astronomers to write in Arabic – also an astrologer at the court of the caliph al-Mansur, who firmly established the Abbasid dynasty – was Masha' allah (Messahalla), whose writings are only known in Hebrew and Latin translations. Masha' allah draws on Indian and Persian sources as well as Arabic and classical, and the Latin translation of his *De Compositione Astrolabii* showed how to construct that basic tool of observation and reckoning of time: the astrolabe. Later Chaucer drew on Masha'allah for his *Treatise on the Astrolabe,* a charming piece of prose, explaining to a 10-year-old boy the use of this scientific instrument. Chaucer's writings, full of references to Arab sources, whether in the form of tales or of learning, show how far such elements had penetrated the general thinking of his day – 100 years after the



translators had completed most of their work.

In such a limited selection of the Bodleian's wealth, of course, there had to be significant omissions. One was a delightful picture of Roger Bacon at work in his study, another the book of maps composed by the Sicilian Arab, al-Idrisi, greatest of all medieval geographers, and a third the first translation of the Koran into Latin, begun in 1142 in Toledo by an English scholar.



With all its imperfections, this translation represented the first Christian attempt to take an objective view of the Koranic text. Four centuries later, at the height of the hysteria aroused by the Ottoman invasions of Hungary and Austria, this same translation was courageously printed in Basel by the Swiss theologian Bibliander – and the Bodleian has a fine 13th century manuscript of the original translation, as well as copies of the two first printings in Basel.

To the Muslim scholars whose work is shown in this exhibition, the Koran was the summation of human knowledge. The source of all knowledge was God's revelation – as indeed it was for their Christian counterparts. Faith inspired all these men, whether expressed in the Oxford motto *Deus illuminatio mea,* the Psalmist's *The heavens declare the glory of God,* or the Koranic *God is the light of the heavens and the earth.* The Muslim custom of beginning every piece of writing with praise and thanks to God reappears in the Latin translations of Islamic works of scholarship. For example, *The Canon of Medicine* of Ibn Sina, translated by Gerard of Cremona in Toledo from Arabic to Latin, begins with, "Let us first give thanks to God . . . whose mercies are manifest upon all the Prophets." Muslim philosophers also threw light on the relationship between faith and reason – as live a question today as it was when Bacon studied Avicenna's commentaries on Aristotle.

What is the point of recalling this story of the transmission of ancient knowledge today – when scientific texts are said to be out of date almost before they are printed? Is the history of the development of the astrolabe likely to be relevant in the age of the computer?

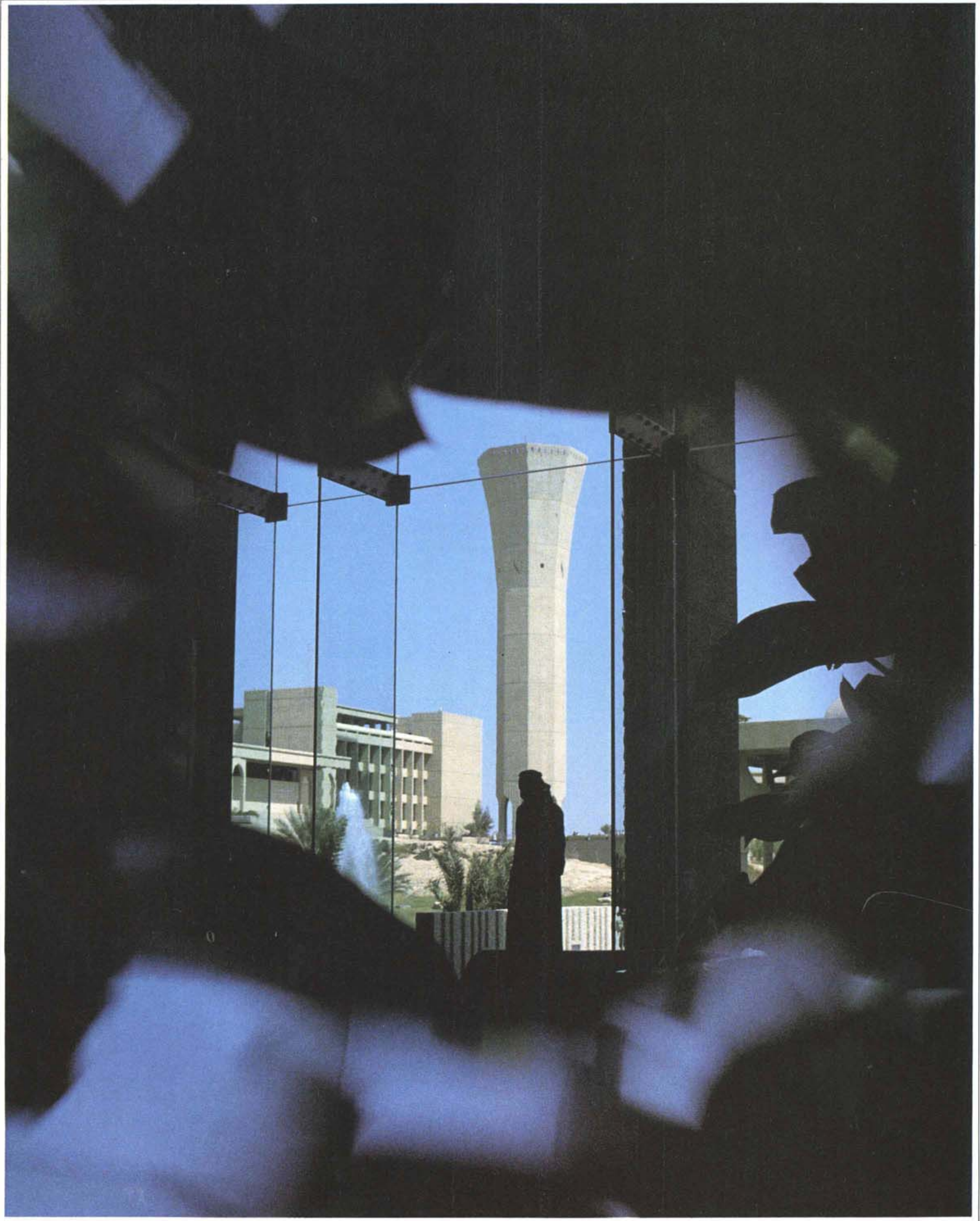
The answer to these questions lies in the fundamental precepts of scholarship – and of human nature. It is human beings who acquire and use knowledge. One constant factor in research is the variable, volatile mixture of emotions and purpose which motivates those who pursue it. Their passion for truth and their boldness in exploration demand a rigorous discipline and an integrity of aim not to be deflected by the jealousies, the insecurities, the ambitions common to man. Intellectual integrity also demands a generosity of spirit, giving credit where credit is due, enhancing the other man's contribution rather than diminishing it.

One lesson can be drawn from the story of 12th- and 13th-century Europe and its advances in scholarship. Relationships between intellectuals can play an important part in times of conflict, in preparing the way for a better future. For it must not be forgotten that the period of the translators was also the period of the Crusades.

The real points of contact, of course, were not on the battlefields of Palestine, but were in the court of Palermo and the libraries of Toledo, where Christian, Muslim and Jewish scholars – using Latin, Greek, Arabic and Hebrew – achieved a cooperation important to the whole future of Europe.

These vital points of contact have largely been forgotten. Bacon, for example, spoke against military endeavor, and took account of Islam's positive contribution to the divine scheme of revelation. He and others had some grasp of the common basis of faith of Muslims and Christians.

Thus a tribute – in gratitude for a long forgotten debt owed by European scholarship to the Muslim world – is neither out of place nor out of date; it is a timely reminder which may smooth the path toward future cooperation, and which illuminates the possibilities of give-and-take between scholars, in a turbulent age. ■



SCIENCE IN THE MODERN AGE

WRITTEN BY RICHARD HOBSON – WITH JOHN LAWTON, ROBERT FRAGA, ARTHUR CLARK AND MARTIN LOVE
PHOTOGRAPHS BY BURNETT H. MOODY AND S. M. AMIN – WITH TOR EIGELAND, ROBERT AZZI, M. J. ISAAC, DICK MASSEY, JOHN CHAMPNEY, WASIM TCHORBACHI, NIK WHEELER, PAMELA ROBERSON, JAMES G. ROSS

More than 1,000 years ago, as Europe languished in the Dark Ages, Islamic astronomers were building observatories, Islamic engineers were developing the windmill – and perfecting the waterwheel – and Islamic scientists were working out the principles of algebra, laying the foundations of optics and even attempting to fly.

This was the era of *Bait al-Hikma,* the "House of Wisdom," an early version of today's "think tanks," from which came translations of Greek mathematical and scientific papers, breakthroughs in geometry and, eventually, discoveries in everything from hydrology to medicine – all of which were transmitted to the West.

As the tides of history ebbed and flowed, however, Europe gradually caught up and surpassed the Islamic world in science and technology – to be, in turn, surpassed by the United States, the Soviet Union and Japan – and by the time of the Industrial Revolution, the Islamic countries, lacking trained manpower and an adequate industrial base, had been eclipsed by technological developments in the West.

Though the Muslim world was, of course, painfully aware of the gap that had opened – and had widened over the centuries – there actually was very little they could do on their own to bridge it. Lacking the infrastructure to develop industry – and the coal to fuel it – all they could do was import knowhow and equipment.

This system of modernization – as distinct from the slow, trial and error approach – is expedient, of course, but poses dangers; it tends to foster dependency on the West and could stifle indigenous scientific and technological initiative – a prime concern of many science policy-makers.

On the other hand, this influx of outside scientific and technological influence – coupled with large scale development programs – has also kindled a new interest in the study of the sciences. Recently, in fact, the number of Arabs pursuing scientific careers has mushroomed. Over the past 30 years the number of Arab students who have earned degrees from colleges or universities in the Arab world has been leapfrogging at a geometric rate: nearly

doubling every five years since the early 1950's. By 1975, there were about 760,000 graduates, and by 1980 close to 1.5 million.

In the sciences – and even more so in technological disciplines – this steadily accelerating pursuit of higher education has been particularly striking. By 1976, some 75,000 Arabs had earned degrees in engineering, 60,000 in agriculture, 50,000 in the basic sciences, 50,000 in medicine and 16,000 in pharmacology, to name only a few fields. It has also been estimated that by 1978, some 24,000 Arabs held doctoral degrees – mainly from the United States, Europe and the Soviet Union – and half of them were degrees in the sciences. In the same year, scientists in the Arab world generated some 2,000 technical papers.

This enormous growth – documented by Lebanese scientist Dr. A. B. Zahlan in his book, *Science and Science Policy in the Arab World* (1980, Croom Helm Ltd., London), has already led to the collection and accumulation of scientific knowledge now being shared with the Arab states and the larger international scientific community. A concerned critic of Arab science, consultant to several international scientific organizations, and leading authority on the application of science and technology to development, Zahlan says that:

> The Arab World is at the threshold of momentous changes that are being heralded by the increasing access to higher education. Within the following two decades, if the trends of the past three decades persist, more than 12 million Arabs will graduate from universities in the Arab world. Of these, at least six million would have received an education in the applied or basic sciences.

What must be added, furthermore, are graduates from universities in the West. According to Zahlan, some 250,000 Arab students were enrolled in universities in Europe and North America during 1980, the latest year for which complete figures are available. That could mean that by the turn of the century, fully 10 percent of the total Arab population will have received a university education – a 20-fold increase over 1975, when only half a percent of the total population had a higher education. And most – more than 50 percent – will have received training in the sciences.

It would be misleading, nevertheless, to imply that this scientific resurgence could be compared with the science of the Golden Age. For one thing, scientific efforts in the Islamic world today are more often focused on applied science – technology – than on pure science. With innumerable practical problems to solve and with the information boom that has led to inceased specialization, today's scientists simply do not have time for much abstract speculation; instead they concentrate on research and development that, they hope, will provide concrete solutions to immediate problems, a philosophy that Saudi Arabia's Third Five-Year Development Plan (1980-85) clearly enunciated:

> Saudi Arabia's general attitude toward science and technology is based upon a traditional respect for knowledge and appreciation of the human effort expended in its accumulation and development. The kingdom has always appreciated the contribution that science and technology can make to social and economic development. Accordingly, the objectives of the national science and technology policy are twofold:... the transformation of society's material conditons through the selection, transfer and management of advanced technology while simultaneously preserving cultural values; and, in the development of the kingdom's natural and human resources, (the objectives) focus on reducing the economy's dependence on foreign manpower and on depletable hydrocarbon resources.

This philosophy also guides the policies and activities of several national scientific organizations that have been set up in the Islamic world in recent years – organizations such as the Saudi Arabian National Center for Science and Technology (SANCST).

Founded in 1977, SANCST is the central body responsible for promoting and coordinating scientific research in the kingdom. SANCST, therefore, tries to combine the best of both worlds; it encourages both internal Saudi research as well as initiatives from outside scientific circles, and has already achieved a remarkable degree of international cooperation in its effort to bridge the scientific and technological gap.

As one example, SANCST has entered into a project agreement with the Canadian National Research Council to help design and test the critical components in a planned national observatory and has signed a technical agreement with the Republic of China in the field of single cell protein manufacture. Its most ambitious international project, however, is SOLERAS, a $100 million joint venture with the U.S. Department of Energy, in which large scale solar energy experiments are being conducted in both countries. Projects include a plan to supply electricity from photovoltaic cells to two villages north of Riyadh and, in the U.S., the design of solar-powered desalination systems. Dr. Bakr Khoshaim, SOLERAS program director in Saudi Arabia, has called the joint project "a model of cooperation between two nations in pursuit of a technology which will benefit them both."

The SANCST organization also sponsors research at academic centers through scientific grants. At Riyadh's King Sa'ud University, for example, scientists and engineers have received SANCST grants to investigate the biosynthesis of protein from hydrocarbons, ways to enhance recovery from Saudi oil fields, and the effect of super-fine sand and saline well water on the compressive strength of locally produced cement mortar and concrete.

At King Abdulaziz University in Jiddah, scientists are developing a nuclear power plant simulator, conducting geochronological and paleomagnetic studies of potentially mineral-rich areas of the Hijaz, and looking into the chemical properties of medicinal plants in the kingdom.

Scientists at the University of Petroleum and Minerals in Dhahran – one of the kingdom's most active research centers – are, with SANCST grants, investigating an array of technical subjects, including: stratigraphic analysis of phosphate deposits in Northwest Arabia, viscosity behavior of Saudi crude oils, the removal of nitrogenous compounds from activated sludge, and the use of residual stress gradients in anti-corrosion designs. One UPM engineer – Dr. Fouad A. Ahmed – has been involved in the three-dimensional recording of Islamic and other civic monuments, a good example of Western technology pressed into the service of traditional values.

Research at King Faisal University, with campuses in Damman and al-Hasa in the Eastern Province, centers primarily on agriculture. Examples of projects under way are testing of new drugs used to treat animal parasites, studies of diseases that affect date palms, and an investigation of the main drainage canal in Hofuf to see if the water can be used for fish cultivation.

The kingdom's newest university, KFU, last December, also graduated a batch of students from its new medical school, and though there are two other medical schools in the kingdom, the KFU graduation was marked by an official ceremony – an indication of the importance the country's leaders attach to the development of highly trained cadres in scientific fields, particularly in the medical sciences.

In history, of course, there is strong Islamic precedent for commitments to medical science. Muslim scientists, for instance, discovered the circulation of the blood in veins centuries before Harvey did, worked out principles of infectious disease and performed delicate eye operations with a skill not duplicated until modern times. During the medieval period, Islamic physicians also founded hospitals throughout Middle Eastern urban centers – including Makkah and Medina on the Arabian Peninsula.

It was particularly appropriate, therefore, when Saudi Arabia, seven years ago in Riyadh, opened the King Faisal Specialist Hospital and, one year later, the related Cancer Research Institute (see *Aramco World*, July-August 1979). Equipped with the most sophisticated medical devices that Western technology can muster – everything from a computerized multiple blood sample analyzer to a cyclotron to produce radioactive isotopes used in cancer diagnosis and treatment – these facilities are model institutions in the region and serve as essential domestic training grounds for Arab medical specialists.

Clearly, Saudi Arabia is ahead in its rapid acquisition of scientific and technological resources – and in its commitment in these fields. But it is by no means the only Arab country backing scientific activity. Egypt, for example, has been a Middle East pathfinder for 30 years ever since the 1950's, when its technical manpower more than quadrupled and four major new scientific institutions were founded: the Supreme Science Council, the Atomic Energy Agency, the Desert Institute and the National Research Center – once ranked as the largest scientific institute in the Arab world. In 1971, Egypt also set up the Academy of Scientific Research and Technology to organize applied research in such areas as food, agriculture and water resources – especially the impact of the Aswan High Dam.

In Syria the Scientific Studies and Research Unit, established in 1972, has focused on applied and industrial chemistry, applied physics, electronics, mechanical engineering, science policy and computer science; it has also conducted studies of housing costs, banking activities, water distribution, telecommunications and land reclamation.

In Iraq, a major oil producer like Saudi Arabia, rapid development of its scientific and technological potential has been given high priority. The Foundation for Scientific Research, established in 1963, today has eight specialized research bodies affiliated with it: the Agricultural Research Center, the Petroleum Research Institute, the Institute for Applied Research on Natural Resources, the Building Research Center, the Palm and Date Research Center, the Biological Research Center, the Scientific Documentation Center and the Directorate General of Scientific Youth Welfare. By 1975, the University of Baghdad was operating six research centers, including one in the medical sciences.

Since 1972, Iraq's Nuclear Research Institute (NRI) has been providing critical technical services to different sectors of the economy, as in its studies of corrosion in oil and gas pipelines and in its production and utilization of radioactive materials in hydrology studies. The NRI has a range of research departments, working on nuclear reactors, physics, chemistry, engineering and instrumentation, biology and geology.

In Lebanon, much of the scientific research takes place at the American University of Beirut, with work at the country's other well-established colleges and universities sparked by the creation of the National Council of Scientific Research, which began awarding research grants in 1968. And in Jordan, the Royal Scientific Society, founded in 1970 as an independent, non-profit research and development organization, has been working in the fields of education, economic research, electronic and mechanical engineering, and computer systems.

Not surprisingly, given the traditional Islamic-world problems with farming, much scientific research has focused on agriculture – and still does today as scientists from Aleppo to Abu Dhabi grapple with the urgent problem of feeding growing populations from depleted land.

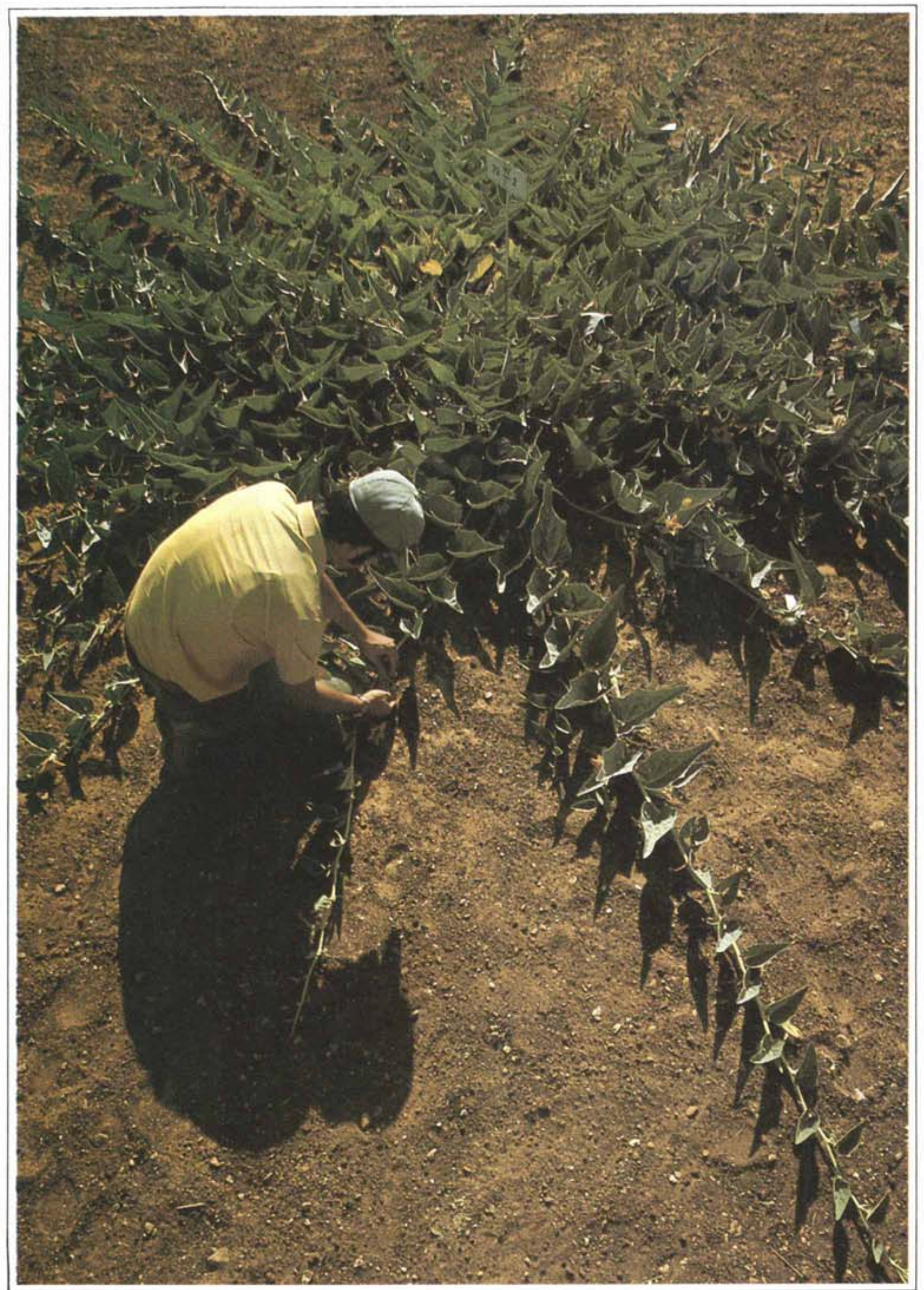
Centuries ago, what is now the Arab East was the granary of the known world, as well as the birthplace of the date palm and the site of ingenious advances in irrigation. Gradually, however, war, pestilence and drought destroyed the region's fertility until, up to a decade ago, extensive agriculture was deemed impossible in the region – 90 percent of which was desert. Today, though, agricultural history is once more being made in the Arab world. In Saudi Arabia, for example, agricultural scientists are growing tomatoes and cucumbers without soil. In Libya agronomists are creating great circles of watered farmland in the heart of the Sahara. In the United Arab Emirates an asphalt carpet has been laid beneath the sand to prevent water loss, and in Syria scientists are developing new "miracle" strains of traditional Middle East crops.

None of these experiments is entirely new to the Arab East. Since the 1960's the Arab Lands Agricultural Development Program (ALAD) has been working hard at improving the productivity of the region, as well as experimenting with the introduction of the "buffalo gourd" (see *Aramco World*, November-December 1972), a protein-rich plant with roots that can reach water even in deserts.

But ALAD's research program is being carried even further by the International Center for Agricultural Research in Dry Areas (ICARDA). An extension of the global network of agricultural scientists who helped bring the "green revolution" to Asia, Africa and the Americas with "miracle" wheat and rice, ICARDA, in 1977, began similar experiments with the basic crops of the Middle East: wheat, barley, lentils, broad beans and chickpeas.

At ICARDA's experimental station near Aleppo in Syria, their scientists have crossed the most hardy local crop varieties with high-yielding international varieties to produce plants that will simultaneously resist disease and drought, tolerate high temperatures and salty soil, and produce a greater abundance of more nutritious, tastier food.

In the five years since its formation, ICARDA, says its Sudanese Director Dr. Muhammad Nour, has made a series of "wonderful breakthroughs" in agricultural



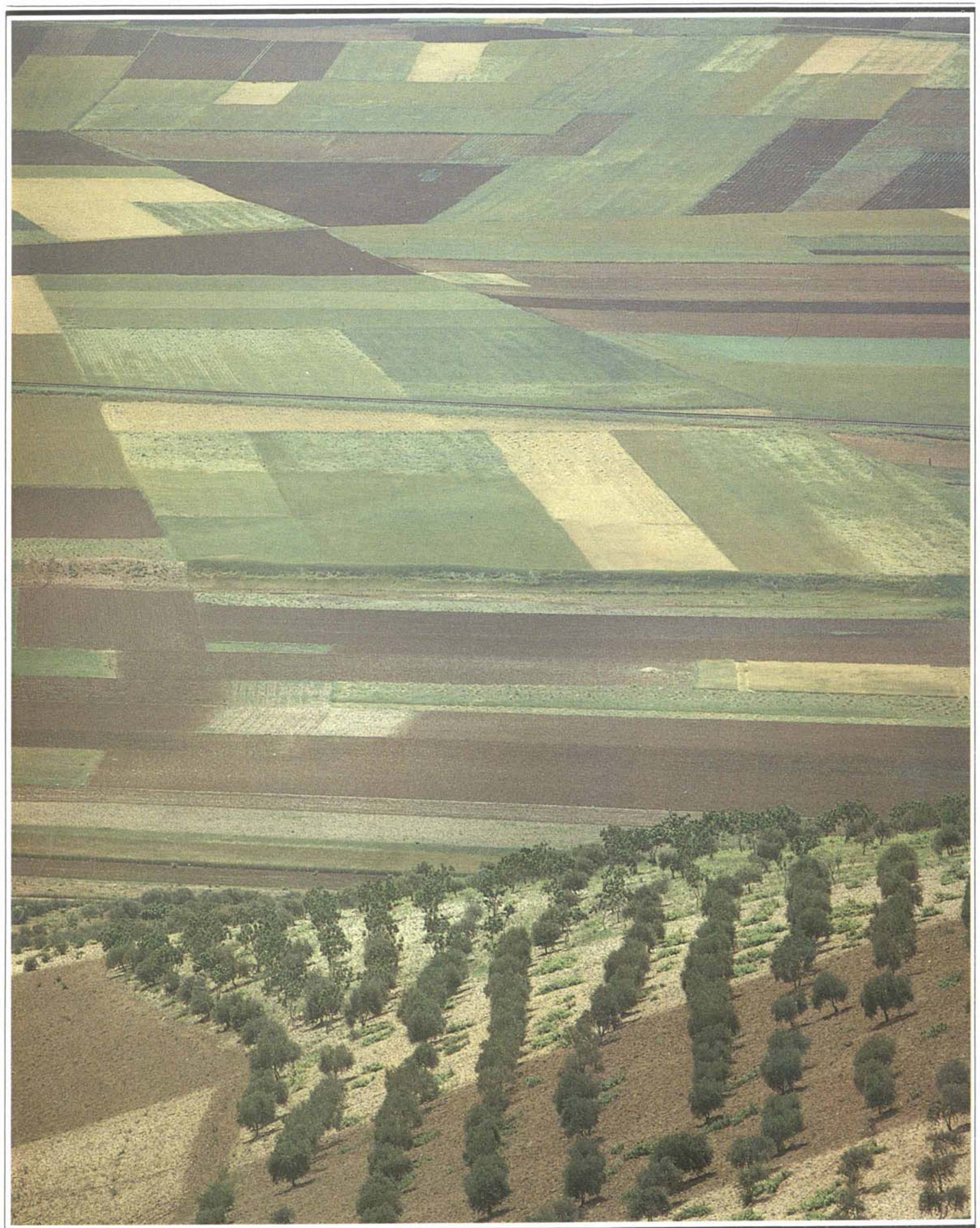
research that are already helping improve the staple diet of the peoples of North Africa and the Middle East. These, says Dr. Nour, include the development of five new types of high-yielding, better-tasting cereal that are currently being incorporated in the growing programs of 25 nations; introduction of a new, more nutritious variety of broad bean in the Nile Valley; and development of a new type of chickpea resistant to a common fungus disease which regularly decimates Middle East pea crops. In addition, says Dr. Nour, ICARDA has trained over 250 agricultural scientists and technicians from all over the Middle East who are now helping improve their own country's food output.

This research, of course, is aimed at increasing output from acreage already under cultivation, but other experiments in Libya and the United Arab Emirates are designed to expand cultivable land. By tapping so-called "fossil" water – which has been locked beneath the desert for thousands of years – and drawing it to the surface and sprinkling it over the sand from huge booms revolving horizontally on wheels – Libyan scientists are creating great discs of farmland in the Sahara. And in the UAE's desert reclamation project, agricultural scientists have laid a three millimeter thick carpet of asphalt under the sand at a depth of one meter. The "carpet" prevents irrigation water from soaking into the sand and also stops salt seeping up from the sub-soil on a five-acre experimental farm in the Salaymat district of Abu Dhabi. As a result of such innovative experiments, UAE crop values rose 76 percent between 1977 and 1980.

Meanwhile, Saudi Arabia has been experimenting with "hydroponics" – growing vegetables without soil. In a type of hydroponics called "NFT" – nutrient film technique – plants are grown in plastic trays into which runs a solution of water and dissolved plant food. Housed in humidity-controlled greenhouses, crops of cucumbers and tomatoes have been harvested in just five to eight weeks after transplanting. More recently, the scientists have also been trying to grow plants in sterilized sand irrigated with a nutrient-packed drip. The sand culture program is exciting, agronomists say, because it can be carried out less expensively than hydroponics but with similar results.

To consolidate these gains in agriculture, as well as in energy, medicine, pollution control, hydrology and many other fields – and to coordinate research efforts – several regional organizations have been set up – another indication of how much science in Arab countries is focused on development. Some examples are the Arab Regional Center for the Transfer and Development of Technology, the Arab Fund for Scientific and Technological Development, and the Union of Arab National Research Councils. Another important group is the Conference of Ministers of Arab States Responsible for the Application of Science and Technology to Development (CASTARAB). Aimed at increasing regional cooperation in various fields of research, CASTARAB first brought together ministers from 18 Arab nations in 1976 in Rabat, Morocco and has scheduled a second conference in late 1982 in Tunis.

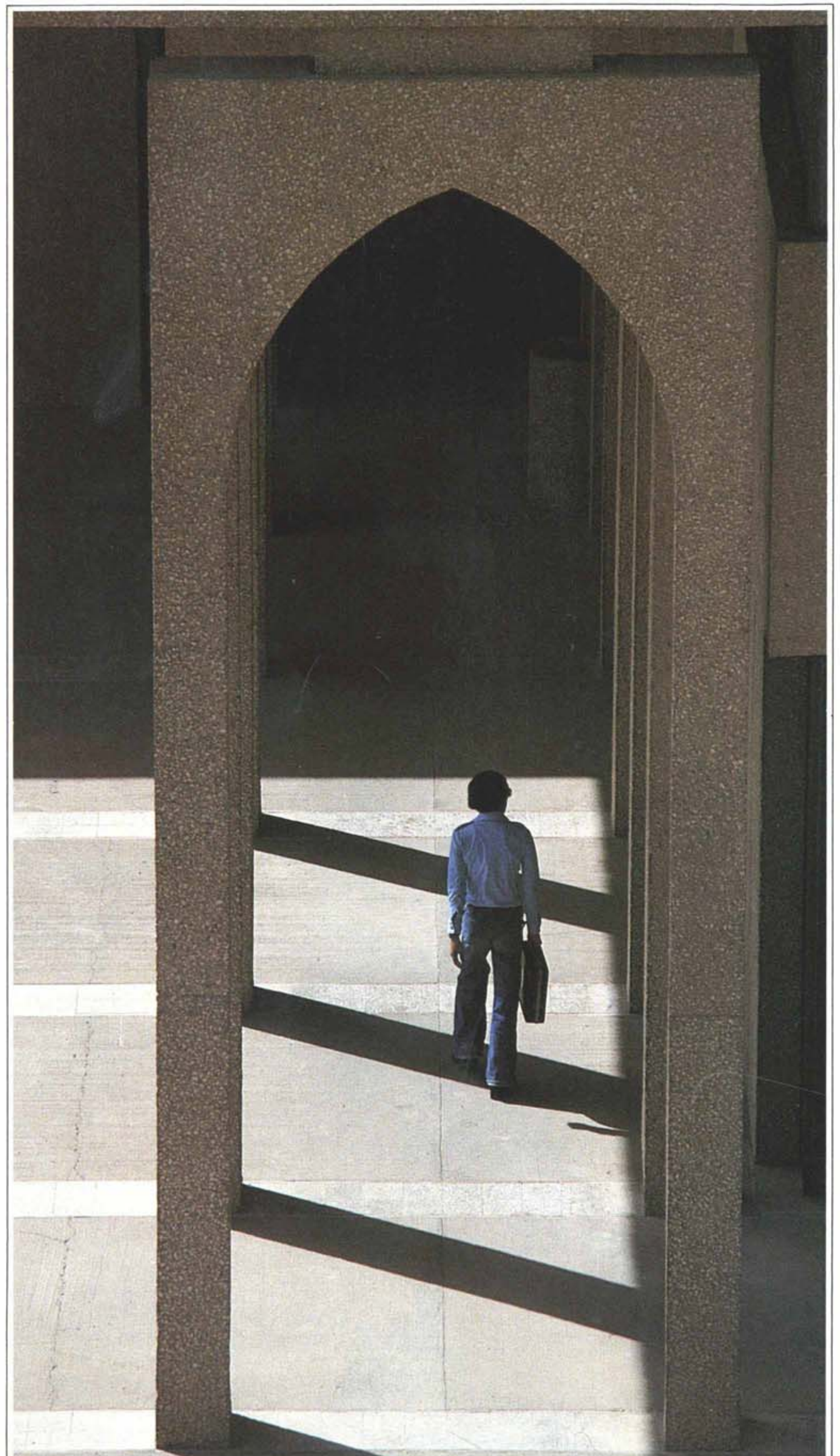
Some countries do more than others, of course; not all the countries in the Islamic



world have been blessed with petroleum riches. As a result, scientists – and potential scientists – frequently emigrate in frustration. Dr. Zahlan estimates that there are now 27,000 Arabs with doctoral degrees, but that fully half have emigrated because of insufficient support in their native lands. "National support for research and development activity," warns Zahlan, "is very low."

Abu Salam of Pakistan – winner of the Nobel Prize for Physics in 1979 – has a similar view. If scientific enterprise is ever to flourish in the Muslim world, Dr. Salam says, it will be necessary to spend $4 to $8 billion a year on research and development, with one-fifth that amount earmarked for pure science as distinct from technology.

Few countries will ever be able to afford an outlay of that magnitude, of course, and even many of the biggest oil producers would not find it easy to allocate such sums to pure science right now in the midst of the massive industrialization programs that are already under way. Nevertheless, a start has been made – at two outstanding centers in the Islamic East for the promotion of science and technology: the Research Institute at the University of Petroleum and Minerals (UPM) in Dhahran, and the Kuwait Institute for Scientific Research (KISR).



At these institutes Muslim scientists are collecting and absorbing scientific and technological knowledge from the world's most highly industrialized nations and – far more significant – are attempting to transform it, adapt it, and redigest it – in a form palatable and usable in their own societies and others in the Arabian Gulf and beyond.

To compare the efforts of these institutes to *Bait al-Hikma* of Baghdad – as some observers tend to do – may seem an exaggeration, but it is not just romantic yearning for the Golden Age; real parallels do exist. Ninth century Islamic scholars, after all, also collected and absorbed a wholly alien intellectual tradition and from an intellectual fertilization cutting across national, linguistic, religious and cultural bounds, built a renaissance upon it.

In Kuwait and Saudi Arabia, furthermore, inquisitive and highly educated native minds are joining others from the Islamic world and the major science centers of the West and Far East. As scholars at the House of Wisdom looked to Byzantium and beyond, those at UPM and KISR are reaching out to Tokyo, to Pasadena – and to points in between.

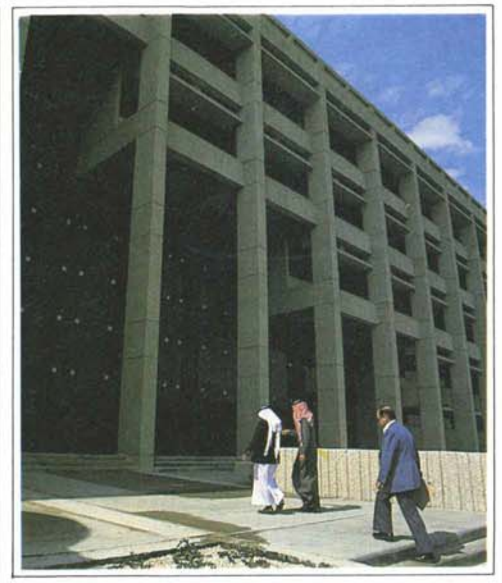
It is important to remember that the Kuwait institute is barely a decade old and UPM's has only been operative since 1977. In a sense, they are the instant offshoots of newly prosperous societies, and while each of the institutes has enunciated a clear determination to *apply* Western technology and not just swallow it wholesale, neither holds any illusions that it can – in the words of a 1978 study – change from "technology taker" to "technology maker" overnight. In fact, the UPM institute and KISR are themselves bold experiments.

At the UPM Research Institute, for instance, scientists last fall took occupancy of the newest, and one of the most advanced scientific facilities in the Middle East. There they are focusing their attentions on such matters as how to predict and control the movement of sand dunes; how to calculate oil spill paths; how to maximize oil and gas production through the simulation of underground reservoirs; how to adapt solar technology to dust-blown regions; how – in an area criss-crossed with myriad steel pipelines containing precious oil, gas and water – to control corrosion; and how to preserve the fragile desert environment as Saudi Arabia engineers its own industrial revolution.

To solve such problems, the institute – housed in a six-story edifice simply called "Building 15" by those at UPM – has organized its scholars into divisions: metrology, standards and materials, geology and minerals, environmental and water resources, energy resources, and economics and industrial development. The top floor of the building is reserved for experiments in petroleum and gas technology – under a roof with glass in-sets specially designed to allow for the dangerous but unlikely event of an explosive accident.

"The new building is unparalleled," says Dr. 'Abdallah Dabbagh, institute director. "It is the most modern scientific research facility in the Middle East."

Even a casual inspection suggests that this is no exaggeration. Built around a utility core spine, it contains offices, conference and filing rooms, more than 100 labs, each supplied with piped nitrogen gas and four types of water – raw, distilled, domestic hot and de-ionized – and each designed to conform to strict environmental standards. In the dimensonal lab, for example – where accuracy of length measurements is essential – temperatures are maintained at 20°C. with a tolerance of only one-third of a degree Celsius. Humidity is kept at under 40 percent, plus or minus 5 percent, and the dust level is minimized to under 700 grains per cubic foot.



The institute's computer power comes from links to UPM's giant IBM 3033 and IBM 370-158. The institute itself also owns mini-computer systems for use by its divisions. In addition, it boasts strategic computer brain power through its online access to the Lockheed Information System data base in Palo Alto, California, and to the System Development Corporation data base in Santa Monica via direct telecommunication hookup through Bahrain.

Utilizing such resources, Dr. Zeini Sa'ati is heading up an effort to establish a computerized information center at the institute. Dr. Sa'ati also is teamed with Dr. Rida Siraj al-Thiga in organizing a group of scientists and engineers in a "computer Arabization" project which could have far-reaching effects both on the work of Arab scientists and on joint Arab-Western endeavors.

Such endeavors are not unfamiliar to institute director Dabbagh – who won a bachelor's degree in geology from the American University of Beirut, and a doctorate in structural geology from the University of North Carolina at Chapel Hill, and spent a year as visiting lecturer at Princeton. But he never forgot his origins – in Taif – and in 1976 he returned to Saudi Arabia where, about two years later, he became director of the Research Institute.

As director, Dr. Dabbagh believes that "transfer of technology does not take place without original applied research."

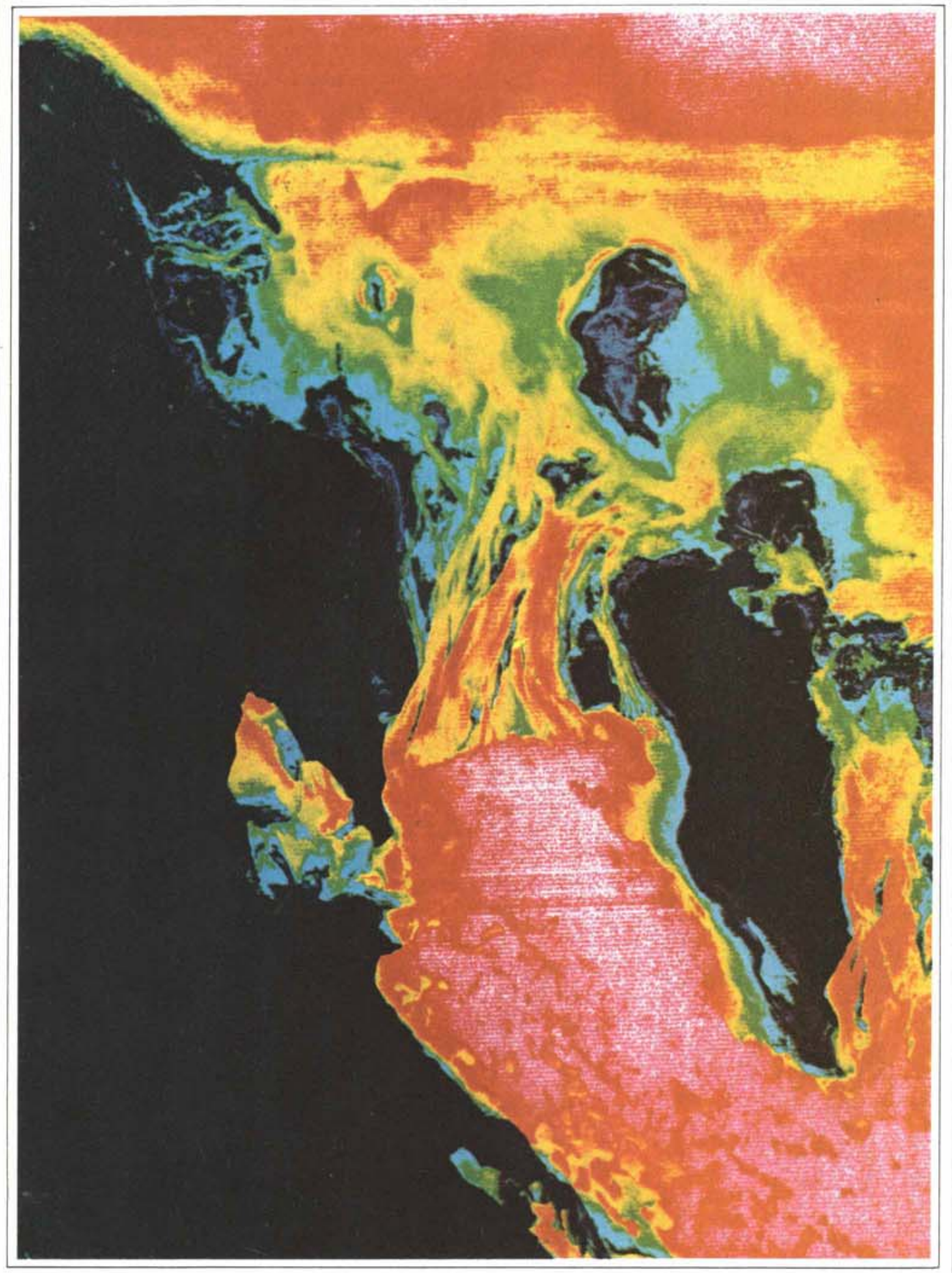
Accordingly, much of the research under way at the institute is directly related to three environmental factors that dramatically affect life in the Arabian peninsula – the sun, sand and sea.

Because Saudi Arabia is drenched with more solar energy in a year than the energy contained in all the earth's conventional fuel reserves, the kingdom has long advocated research into the solar alternative (See *Aramco World*, September-October 1981). In fact, the kingdom has been a major international sponsor of such research – which is now being conducted at four of the kingdom's universities. It was the institute, however, which spearheaded the solar movement in Saudi Arabia, and which recently installed, on the roof of Building No. 15, a comprehensive monitoring station to measure 16 solar and meteorological parameters to help scientists gauge the energy potential of Arabian sunlight.

According to Said Ahmed Said, a Sudanese mechanical engineer with degrees from Brighton Polytechnic and UPM, the station will be connected to an automatic data acquisition system, including a Hewlett Packard 3495A multiplexing scanner that allows measurements to be taken on sequential, random or single scanner channels. The system controller, the Hewlett Packard 9845B, processes the measurements made through the data acquisition system and presents the results in usable formats.

If Arabia's blistering sun is a blessing in disguise, its drifting sand is not; sand, in fact, threatens billions of dollars of infrastructure: super highways, gas processing plants, buildings and even towns. The institute, therefore, has assigned sand experiments a high priority. Simultaneously, scientists in two separate divisions at the institute are working on techniques to predict how sand moves and to counteract encroachment. One approach is a collaborative effort by Uruguayan-born Danilo Anton and Ghanaian Kwasi Bohfah, who have mapped out a strategy to combat sand encroachment.

"Our experience shows that a final solution to the sand problem initially requires



the mapping, classification and evaluation of sand deposits in upwind areas," says Anton. "It may also be necessary to install sand traps, wind stations, tracers and piezometers. One single *shamal* season – often one single sand storm caused by those fierce northerly winds – can give an idea of local sand paths, information needed for detailed designs of roads, power lines, runways, communities and industrial plants."

Meanwhile, Bohfah, who holds a Ph.D. in aeronautics from the California Institute of Technology, has conducted extensive experiments with a UPM wind tunnel to determine how such sand formations as parabolic dunes move in a given wind field.

Another, more theoretical approach is proposed by Dr. Husseyn Murat Cekirge, who uses an IBM 3033 computer to model sand dune behavior. If successful, Cekirge's analysis will provide a predictive model of how sand dunes migrate over time, a notable contribution to the theory of sediment transport and a possible breakthrough for those working on the practical applications of such theories.

Cekirge's team of Saudi, Turkish and American co-workers in the institute's water resources and environmental division is also engaged in a study of oil pollution in the Arabian Gulf, the world's busiest supertanker shipping lane. By computing convective and tidal currents on their hydrodynamic model and approximating wind-induced currents – by measuring wind velocity 10 meters above the water's surface – the team has calculated the likely movements of hypothetical spills originating at varying locations and at different times of the year.

In another project, David Tarazi, acting head of the environmental division, is using mobile meteorological laboratories that are, he says, capable of monitoring "all the parameters required by the Meteorological and Environmental Protection Agency in Jiddah, as well as those of the U.S. Environmental Protection Agency." Laden with equipment, these vans give scientists the flexible means to track factors that affect air and pollution.

Saudi Arabia's hopes for the immediate future depend, of course, on the efficient exploitation of its hydrocarbon resources – and the Research Institute is playing a role. Eventually, says Dr. 'Ali Ma'adah, head of the division of petroleum and gas technology, "We will have about 20 laboratories equipped with the most up-to-date equipment in the field – to carry out research vital to the Saudi petroleum and petrochemical industry."

Currently, researchers are studying the characteristics of reservoir liquids and gases, analyzing of drilling core samples and developing a data bank on Saudi oil and gas fields. They also are probing downstream hydrocarbon industries – petroleum refining, gas treatment and processing, and petrochemicals – all important to the new industrial cities of Jubail and Yanbu'. Plans to experiment with petrochemical products are also being discussed that may reduce the kingdom's reliance on expensive imports. One example is the manufacture of paper from plastics instead of from wood pulp.

Water desalination is another crucial field, and scientists in the petroleum and gas technology division are studying the efficiency and economy of methods such as distillation or reverse osmosis. They also are studying existing plants in an effort to improve their capacities, reduce corrosion and cut down on the formation of precipates inside heat exchangers – all problems associated with the treatment of seawater and brackish water.

The problem of corrosion is the bailiwick of Dr. Alexandar Vajda, an urbane Hungarian-born scientist, who has undertaken a survey of Jubail's industrial area. At a 20-square-kilometer site some 100 kilometers north of Dhahran, his staff of 30 assistants have dug a grid pattern of 800 holes, none less than 90 cm. deep; approximately 1.5 kilos of earth was excavated from each hole. Hauled back to the laboratory, these samples are tested for chlorine, moisture and sulfate content, conductivity, acidity and resistivity.

Results already established confirm that corrosion will pose serious maintenance problems at Jubail Industrial City. But with the kind of data Vajda and his team are producing – six detailed volumes of information have been produced in just one and a half years – more effective ways of combating corrosion may be found in time. Under study are the possibilities of passing electric current over metal surfaces, coating corrosion-prone surfaces with epoxy, using chemicals to neutralize acid in water and applying bactericidal agents. The institute also is planning to build an experimental desalination and corrosion research station on the Arabian Gulf shore as the kingdom's primary facility for testing in these fields. Dr. Vajda says he is optimistic that the station will be "equivalent to the best corrosion centers in the world."

The institute also is researching ways to utilize surplus sulfur, a by-product of the kingdom's massive gas-gathering and processing network.

Further afield, the institute has recently subscribed to NASA's LANDSAT satellite program, in which orbiting multispectral scanners record highly detailed data about the earth's surface in digital form – data that can be decoded to produce extremely useful images. (See *Aramco World,* March-April 1982). When color-enhanced, these vivid and almost psychedelic pictures – especially useful in Saudi Arabia because of the relative lack of distortions from cloud cover and surface vegetation – can be used in geology, hydrological and agricultural studies, census-taking, land use planning, monitoring marine ecosystems, pollution control and other areas.

The UPM Research Institute is growing rapidly with its staff of 150 full-time employees expected to mushroom to 350 or 400 by 1984. Optimistic that one day it may be entirely self-supporting, it already has 13 completed research contracts from the government or private industry to its credit and some 20 others in progress.

Among contracts completed or under way are a reservoir simulation project for the Ministry of Petroleum and Mineral Resources, a model of oil spill trajectories for Aramco, a study of air pollution for the Saudi Arabian Fertilizer Company, and a study of the water distribution system in the capital of Riyadh for the Ministry of Agriculture and Water Resources.

Whether the institute will eventually turn from applied to pure research, putting it in a league with the world's high-powered think tanks, is a question Saudi Arabia cannot answer now. For what the kingdom needs – and what the Research Institute hopes to provide – are immediate, practical solutions for a nation moving headlong down the road to industrialization. In the words of its director, "We are looking to the problems of today."

In Kuwait something very similar – if older – is happening at the Kuwait Institute for Scientific Research (KISR).

Established in February, 1967 by the Arabian Oil Company Limited of Japan, to carry out an obligation incurred under its oil concession agreement with the Kuwait government, KISR is conducting experiments that its scientists hope will help solve national and regional problems. One high priority project, for example, involves attempts to increase local food production – a difficult task in Kuwait's arid climate.

Researchers are also studying methods of removing metal and chemical pollutants from millions of gallons of waste water poured by Kuwait's oil refineries into the sea each day; if they could remove the pollutants, the waste could be reused for irrigation, and pollution in the Gulf would be reduced – another KISR goal.

The scope of this work represents a substantial change from KISR's modest beginning. Back in 1967, KISR had a total of four Japanese scientists and one division, but by early 1981 had 66 scientists and 91 researchers – mostly Arab – and five divisions dealing with food resources, environment and earth sciences, engineering, petroleum and minerals, and techno-economics.

Applied research, of course, has a dramatic ring, but Souheil Tawil, manager of KISR's Publications and Public Information Department, quickly makes it clear that KISR's expectations are realistic. "We're not out to recreate the wheel," he says.

KISR's projects seem to support that view. Almost without exception they are focused on problems directly identifiable with Kuwait and its neighbors – such as the ecology of the Arabian Gulf.

Described by the environmental information agency Earthscan as "one of the world's most fragile seas," the Gulf today must cope with the potentially dangerous input of the world's heaviest concentration of water desalination plants, more than 20 oil refineries and petrochemical, fertilizer and natural gas plants – plus untreated sewage from the burgeoning cities of the Gulf and potential spillage from the 100 tankers that normally sail through the Strait of Hormuz each day.

Because it is shallow and almost landlocked, these polluting effects last longer in the Gulf than in the open seas; there is no way for the Gulf to flush the pollutants into the Arabian Sea. KISR, therefore, is trying to accumulate data by identifying pollutants – a step towards recommending abatement methods.

KISR's interest in the Gulf also includes sea food. Appropriately, since fish play an important part in the diets of both Japan and Kuwait, KISR's early activities focused on fish; even today, the Agriculture and Fisheries Department still accounts for one quarter of the institute's staff, largely because shrimp – one of the department's main concerns – is Kuwait's second largest natural resource. In 1981, in fact, each five-pound box of Gulf king prawn was bringing as much as a barrel of oil on Japanese and American markets; shrimp, moreover, is a renewable resource and thus could still be earning money for Kuwait long after its non-renewable petroleum runs out.

In recent years, however, over-fishing, pollution and destruction of coastal breeding grounds – by land reclamation – have drastically reduced the Gulf's shrimp population. From a peak of about 9,000 tons annually in the 1960's, shrimp landings by Kuwaiti fishermen have dropped to about 4,500 tons a year.

KISR, therefore, has zeroed in on ways to safeguard the shrimp industry. Between 1972 and 1979, KISR hatched, reared and released into the Gulf over 120 million young shrimps in an effort to re-stock the declining shrimp population, but subsequently abandoned the program when harvests continued to fall and, in 1980, it decided to raise young shrimps and fish to marketable size on land. The institute built 20 large ponds – 10 each for shrimp and fish – at al-Khiran in southern Kuwait, and last year marine scientists began testing different rearing methods in two of them; they hope to try, for example, the 'raceway' system – a complex of fast flowing canals in which shrimp put on weight quickly by constantly swimming against the current – and thus absorbing more food.

Another concern for KISR is energy needs after petroleum resources are exhausted. Accordingly, in 1976, the institute launched a solar energy program that has already produced cooling systems to replace air conditioners in greenhouses and homes. KISR has also experimented with a kindergarten in Kuwait City – where solar collectors installed on the roof heat water – and has helped design and build an experimental solar power station; early this year it was still not operating, but plans call for it to convert the sun's rays into energy for use, primarily, in the distillation of fresh water from the sea.

As millions of gallons of water are produced each day in Kuwait by an energy-hungry evaporation process, KISR scientists are continuously seeking new power-thrifty desalination methods. Like scientists at the UPM institute, they are experimenting, for example, with "reverse osmosis," in which ultra-fine filters are used to strain salt from sea water. This process is already being used at desalination plants in Gulf states.

Scientists at KISR are also testing the effect of heat, humidity and sand abrasion on imported building materials to determine which ones are best suited for Kuwait; developing a computerized library management system; and assessing methods of recycling industrial waste – including thousands of discarded automobiles. In fact, so many experiments are under way at KISR that the institute is fast outgrowing its facilities. Early this year, buildings originally designed as garages were being pressed into service as offices at KISR headquarters on the outskirts of Kuwait City, as workmen raced to complete a new KISR complex nearby.

The complex is essential. Since the Kuwait government took over the running of the institute from the Arabian Oil Company in 1973, KISR has quadrupled in size and now boasts more disciplines than many older institutes in the West. Indeed, its scope is such that it provides Kuwait with a wide range of on-the-spot expertise

to help solve general problems, but also enables the institute to set up multidiscipline task forces to tackle specific ones.

A special task force, comprising two metallurgists, an electrologist, two chemists and several engineers, has opened an investigation into the chronic problem of sea water corrosion in the cooling of local industries; this corrosion costs Kuwait millions of dollars a year.

Originally, most of KISR's research was directed from within, but in recent years it has become increasingly more responsive to outside needs. At present, about 20 per cent of the research carried out at KISR is supported by clients through contracts or specific grants, and KISR hopes to boost that to at least 50 percent of total research volume by 1984.

Unfortunately, KISR has discovered, old habits die hard. Thus many Kuwaitis still prefer to call in Western expertise rather than turn to KISR. For example, Dr. Adel Halassa, head of KISR's Petroleum, Petrochemicals and Materials Division, spent 17 years working for Firestone in America, and was considered an expert. But as soon as he got back to Kuwait people would say, "Who do you think you are – a Bedouin trying to tell us about plastics?"

"They've gotten used to calling in outsiders every time they have a problem," says Halassa. "I say: 'Give *us* your problem. Let us in the door.'"

This is changing slowly. Since many of the problems being tackled by KISR, such as corrosion and desalination, are common to other nations of the Gulf, the institute hopes eventually to establish itself as a regional scientific center. But again, says Suheil Tawil, the main problem is "establishing credibility."

So far, in fact, the institute has not done too badly. KISR operates one of the few all-Arab crude oil analyzing laboratories. Its Complete Arab Telex (CAT) with simplified keyboards of one character per Arabic letter, regardless of how many forms it has, is reportedly nearing commercial production for the Arab world.

KISR's solar house is only a short walk from the institute's central building, but other projects are more distant. The little shaikhdom of Kuwait – with a total land area of 19,295 square kilometers (7,332 square miles) – is sprinkled with KISR installations: a shrimping and marine biology station on the coast at Salmiya, a desalination project at Doha, and – a particularly important project in today's ecology-conscious climate – the site of a projected national park at Salmiya.

To Samira Omar, the national park will be vital. A Kuwaiti and an assistant research scientist at KISR, she holds an M.S. degree from the University of California, Berkeley, in range management, and originally had planned to return to Berkeley to continue her studies. Then, however, she got involved in a nine-month project, when KISR was asked to plan the park – on a 20-square-kilometer site at Salmiya (7.6 square miles) and to report on the geological and geomorphological aspects, and the flora and fauna of the region.

Like Dr. 'Ali's computer center, Samira Omar's park will be a challenge. In a country with as harsh a climate as Kuwait's, and a fairly substantial livestock population to support (450,000 sheep and 28,000 goats), Samira's expertise in range management is obviously of practical value. In seeking better forage, for example, she has experimented with saltbush – a plant with a high protein content and a degree of resistance to salinity. Inside a greenhouse only steps away from KISR's four-story central building, she contrasts the growth of rows of *'arfaj*, as saltbush is called in Arabic, some nourished with organic fertilizer and others with distilled water.

Samira's work suggests the role of KISR. As Kazem Behbehani, deputy director general of the institute, put it, "The needs of the area dictate our policy." And one of these needs is people like Samira: a trained Kuwaiti able – and eager – to contribute scientific knowhow to KISR.

To provide for such needs, KISR seeks bright young men and women and sponsors them for training programs abroad; at present there are Kuwaitis working towards M.A.'s and Ph.D.'s at American and British universities on KISR scholarships. For each year of study abroad, the scholarship recipient is expected to work one year at the institute.

Although priority in employment is given to Kuwaiti nationals, KISR's staff is an international one: the 62 Ph.D.'s currently on the staff earned their degrees at universities in 14 countries, principally in the U.S. and Great Britain.

Their work, so far, has ranged from the exotic to the historic. In November 1978, for instance, the institute was asked to solve a rush of flying saucer sightings by army officers, policemen and oil company personnel in Kuwait. KISR agreed, launched an investigation and came up with its conclusion: the UFO's were probably reflections of fumes from Kuwait's oil fields.

KISR has also tried to break the secret vegetation cycle of the desert truffle – so that this expensive wild delicacy, once favored by the pharaohs, can be cultivated at the cost of ordinary mushrooms.

None of these problems may equal the theorems developed at the House of Wisdom 10 centuries ago, yet all contribute to what is clearly a revival.

Such institutes as KISR and the research center at UPM may be the highlights of Arab science in the modern world, but they – and such other organizations as SANCST and CASTARAB – are by no means the only routes by which scientific progress is spreading. Because of the sheer size of its massive five-year development programs, for example, Saudi Arabia has drawn to the kingdom many, if not most, of the largest and most advanced corporations in the industrialized world – and with them the fruits of their highly sophisticated research and development programs.

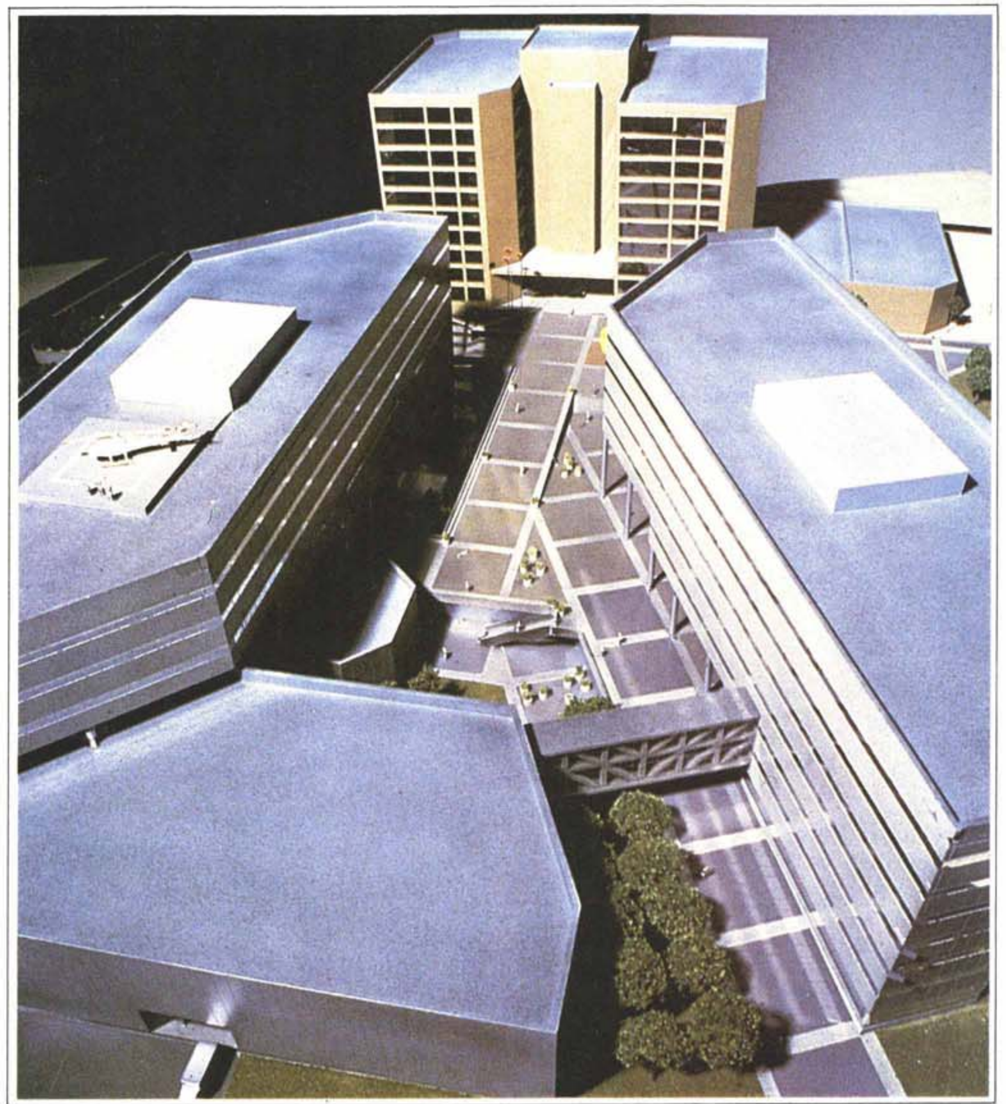
This, to be sure, is a transfer rather than a development of science, but its impact is important, nonetheless. Just as the Islamic world's scholars had to absorb Greek learning before branching out on their own, so today its scientists and technologists must absorb whatever the industrially advanced nations have to offer before they can begin to make original contributions.

In Saudi Arabia, for example, the government has recently taken steps to transfer to the kingdom highly sophisticated geoscience technology on which Saudi Arabia's geologists and geophysicists at Aramco depend so heavily in the development of oil fields and the endless search for new reserves of petroleum.

Until recently, Aramco had relied heavily upon geoscience centers outside the kingdom – mainly in Croydon, England, and in the U.S., where specialists were available to process the reams of data used to answer highly specialized questions concerning exploration and petroleum engineering. Now, even this gap in domestic knowhow is being bridged – at Aramco's spanking new Exploration and Petroleum Engineering Center (EXPEC) in Dhahran.

EXPEC comes not a moment too soon. Engaged in a massive campaign to train engineers, geoscientists, skilled craftsmen and technicians to fully operate and manage the kingdom's hydrocarbon and petrochemical industries, Saudi Arabia must have the technical knowhow readily available – not only on Saudi soil, but near the center of operations. EXPEC, together with the nearby University of Petroleum and Minerals and the associated Research Institute, insures it.

Connected by an underground walkway to Aramco's existing headquarters office



complex, EXPEC consists of a seven-story Exploration and Petroleum Engineering Building and a three-story Computer Center, which together contain 37,533 square meters of space (404,000 square feet). Another seven-story building – the Engineering Building – is nearing completion, as is the second of two major new laboratories.

EXPEC's vanguard project – and, in a sense, its linchpin – is the Computer Center, which came on stream in early 1982. Its brain power, for example, will consist of three of the largest computers IBM makes, the "3033," and one IBM 370-168, forerunner of the 3033. With one 3033 already installed, the center currently has the capacity to compute millions of instructions per second, a rate that will increase significantly this month when the second 3033 is installed and again in September when the third goes in.

EXPEC also contains – or will soon – state-of-the-art reservoir simulation and seismic processing technology, the latest in geologic full-color map plotters and such other high technology equipment as impact printers, laser printers and multiple electrostatic plotters. It will also feature a library of 30,000 magnetic tapes.

Already, the Computer Center is processing data collected by Aramco seismic crews working in the Rub'al-Khali (Empty Quarter) and elsewhere and the amount of data is expected to increase exponentially in coming years due to technological breakthroughs.

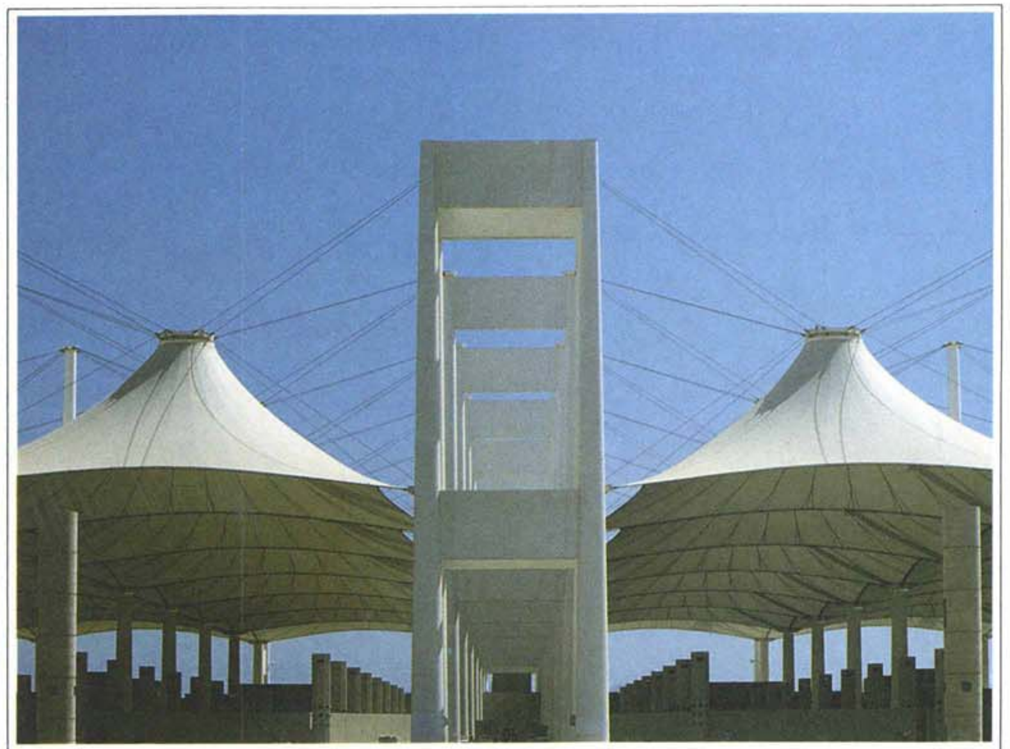
The Central Dhahran Laboratory II, which will be completed later this summer, will be equipped and staffed to carry out detailed analysis of crude oils, including those from recently discovered commercial reservoirs. Scientists housed within this two-story, 5,389-square meter (58,000-square foot) building will also conduct routine and sophisticated analyses of rock samples retrieved from drilling sites. From these studies, scientists can ascertain such phenomena as the relationships between pressure, volume and temperature in underground reservoirs and determine the salinity, sulfur content and grade of crude oils – crucial information to the reservoir and production engineers charged with developing Saudi Arabia's oil and gas reserves in the most efficient way advanced technology will allow.

Space has also been set aside in the central laboratory to serve other scientific activities at Aramco – such as preventive medicine, corrosion control and metallurgy.

Eventually, a total of 2,700 persons – operators to research Ph.D.'s – will work at EXPEC and the new Engineering Building, essentially consolidating, but also enlarging, the field and office staffs, study groups and other specialists that previously were stationed in Europe, the U.S. or at other locations in Saudi Arabia.

In the case of EXPEC – and most petroleum technology – the transfer is direct and the equipment and knowhow is largely unmodified. But there are areas too in which outside technology has been altered and improved. Aware of the sometimes preposterous – and costly – consequences of importing the products of Western technology and then discovering that they are inappropriate, Arab countries are beginning to generate their own solutions to pressing problems. Indeed, the existence of Arab research centers and other scientific institutions indicates the degree to which Arab minds are focused on these issues: how best to press modern science and technology into the service of development and simultaneously generate indigenous scientific and technological activity.

One of the most visible signs of the successful adaptation of outside technology is in the fields of construction engineering and architecture. A rich Islamic tradition has produced forms still extant and still remarkable for their efficiency, economy, beauty and the extent to which they are suitable to local climatic and social conditions. Examples include the domed

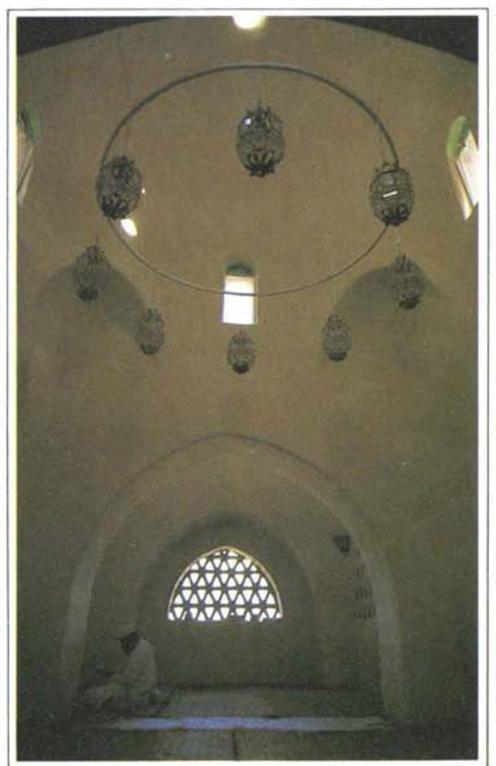


roof, the inner courtyard – often with a fountain at its center – and the windcatcher or wind tower, an ancient form of air conditioning. Jolted by the inappropriate application of Western building forms to the Middle East, a handful of prominent Arab architects have founded a modern movement in Islamic architecture that, in some cases, preserves traditional forms and building techniques, and, in other cases, incorporates new technology in the construction of modern buildings based on traditional forms.

These modern Arab or Muslim architects – either educated in the West or at schools that now exist in Cairo, Baghdad, Beirut, Damascus, Amman, Tunis, Alexandria, Khartoum, Riyadh, Dammam and Aleppo – have exhibited independent thinking and have clung to their own cultural identity.

Internationally famous Hassan Fathy of Egypt has been the most prominent and persistent voice in this movement for some 40 years. Resurrecting the time-honored traditions of domes, vaulted arches, courtyards, mud brick construction – and an approach to modern urbanism that emphasizes the Islamic principles of oneness and unity – Fathy has influenced many other Arab architects. One, also a Muslim, is Fazlur Khan of the American architectural and design firm of Skidmore Owings and Merrill, he not only accepted Fathy's philosophy, but applied it to the construction of buildings that *are* well-suited to the Middle East, but also highly dependent on Western technology.

A notable example of this is the roof design for the Hajj – or pilgrimage – terminal at the new Jiddah International Airport, in which Khan played a major role.



The roof is actually a system of 210 separate, suspended tents – a modern version of the traditional desert dwelling – using a high-technology teflon-coated fiberglass fiber (see *Aramco World*, July-August 1981).

Commenting on the importance of a knowledge of Islamic tradition when designing modern structures, Khan said, "In 1976, I made the Hajj myself, so I have direct familiarity with this Islamic rite. In designing the terminal to receive incoming pilgrims, we wanted to create an environment similar to that at the plain of Arafat."

Khan continues, "Western technology creates a great temptation to take it without transformation which makes structures quickly irrelevant. By transformation I mean adapting Western technology to the sociological and climatic conditions of the people who will use or live in the buildings created from it. It doesn't make sense, for example, to build all these glass boxes in the desert for a people who, over hundreds of years, have developed their own traditional forms."

This transformation of technology is in many ways the key to any scientific resurgence among the peoples of Islam, since it is only when technology is adapted by those who use it that genuine scientific activity can take root and original experimentation can flourish. And while international gatherings on the topic of science, technology and development are important, it is, in Zahlan's words, "the collective commitment to the joy of learning and scientific discovery" that ultimately will determine the degree to which scientific work becomes possible in the Islamic East during this period of intense and rapid change.

All these examples – of research and development, of vital transfers of technology, of scientific experiments in applied fields – suggest the level of science and technology in the Middle East today – and the extent of the commitment that some Muslim countries have made. As in the past, when farsighted caliphs sponsored and supported the scholars who made the Golden Age possible, enlightened leaders today are providing generous patronage of scientists – and potential scientists. Together with the recent expansion in scientific and technological research such a commitment could yet produce a resurgence in Islamic science worthy of its historic antecedents. ■