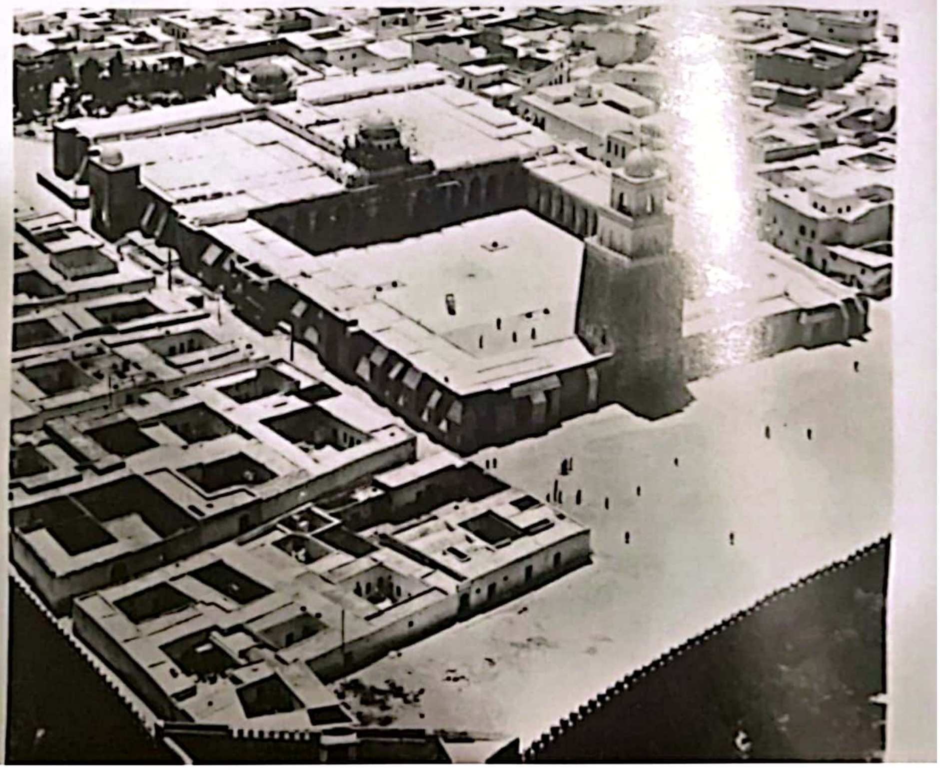
The mosque

Prayer is established at four levels: the individual, the congregation, the total population of a town and the entire Muslim world. For three of these there are distinct liturgical structures. The first is the *masjid*, a mosque used for daily prayer by individuals or small groups but not for the Friday worship; it therefore has a *mihrāb* but no *minbar* (pulpit). The prayer-rug also corresponds to this level. The second is the *jāmi'*, the congregational or Friday mosque; used for the main weekly service, it is normally much larger than a *masjid* and provided with minbar. The third is the *'idgāh* ('place prayer'), illustrated in pl. 5. Within the liturgical types a range of architectural variation is possible, and this page illustrates three of the most important.

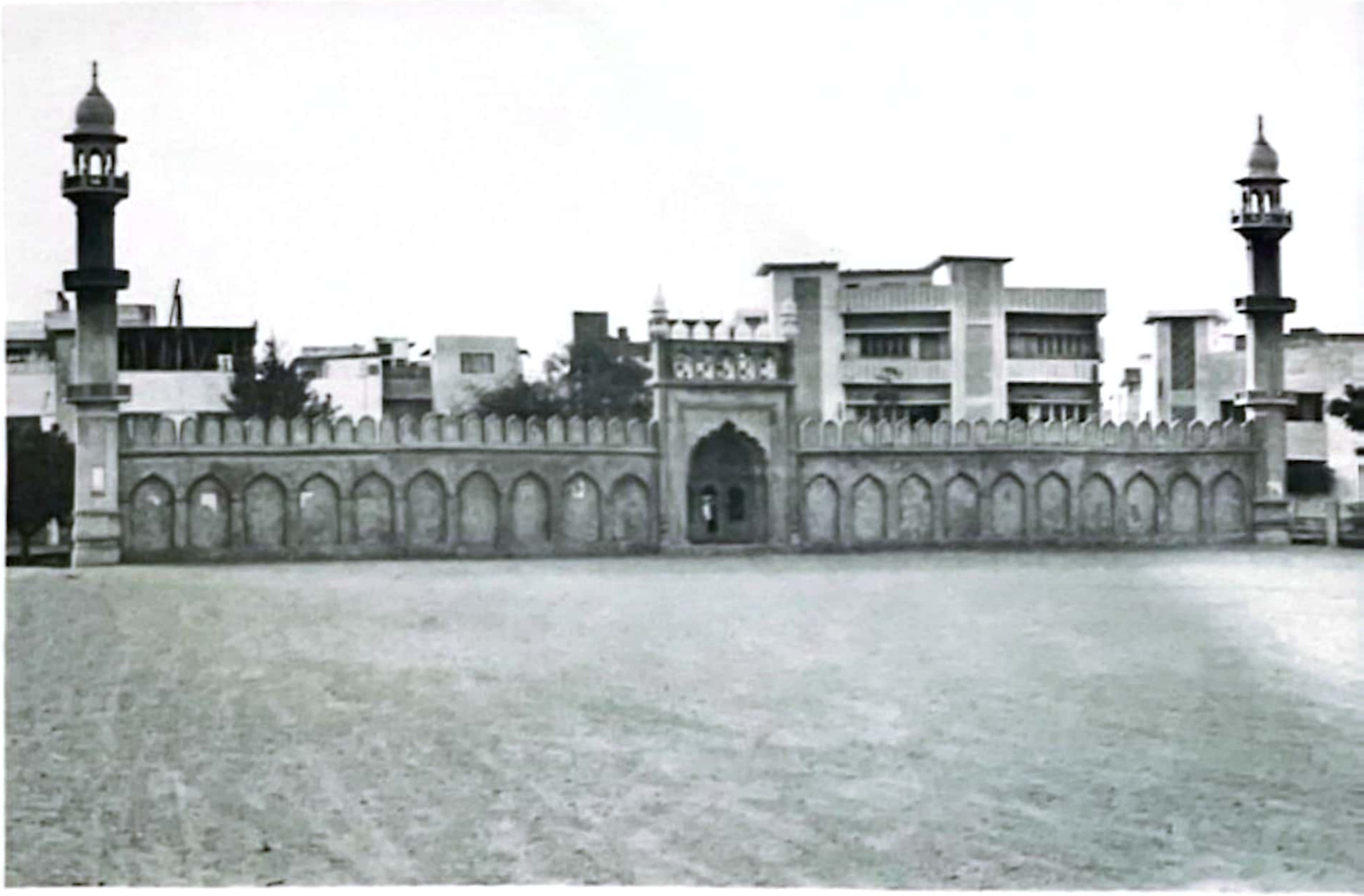
The Ottomans developed the monumental centralized mosque, covered by a dome and buttressed by semi-domes. The mosque of Sultan Ahmet in Istanbul, known as the Blue Mosque (*above*), was begun in 1609 and finished in 1617. Four minarets flank the sanctuary, and two more the courtyard to the right, though liturgically only one is needed. In the foreground are the *madrasa* and the mausoleum of the pious young sultan, who, during the construction, laboured every Friday beside the builders. (2)



In North Africa and Spain an older type of mosque is found, consisting of a vast rectangular hall, the interior divided by rows of columns. At Qairouan, in Tunisia, the Great Mosque was built in the middle of the 9th century. Outwardly plain and lacking in architectural distinction, its only striking features are the minaret and domes over the entrance and the *mihrāb*, marking the terminal points of the *qibla īwān*, or axial aisle, which is elevated above the other aisles. (3)

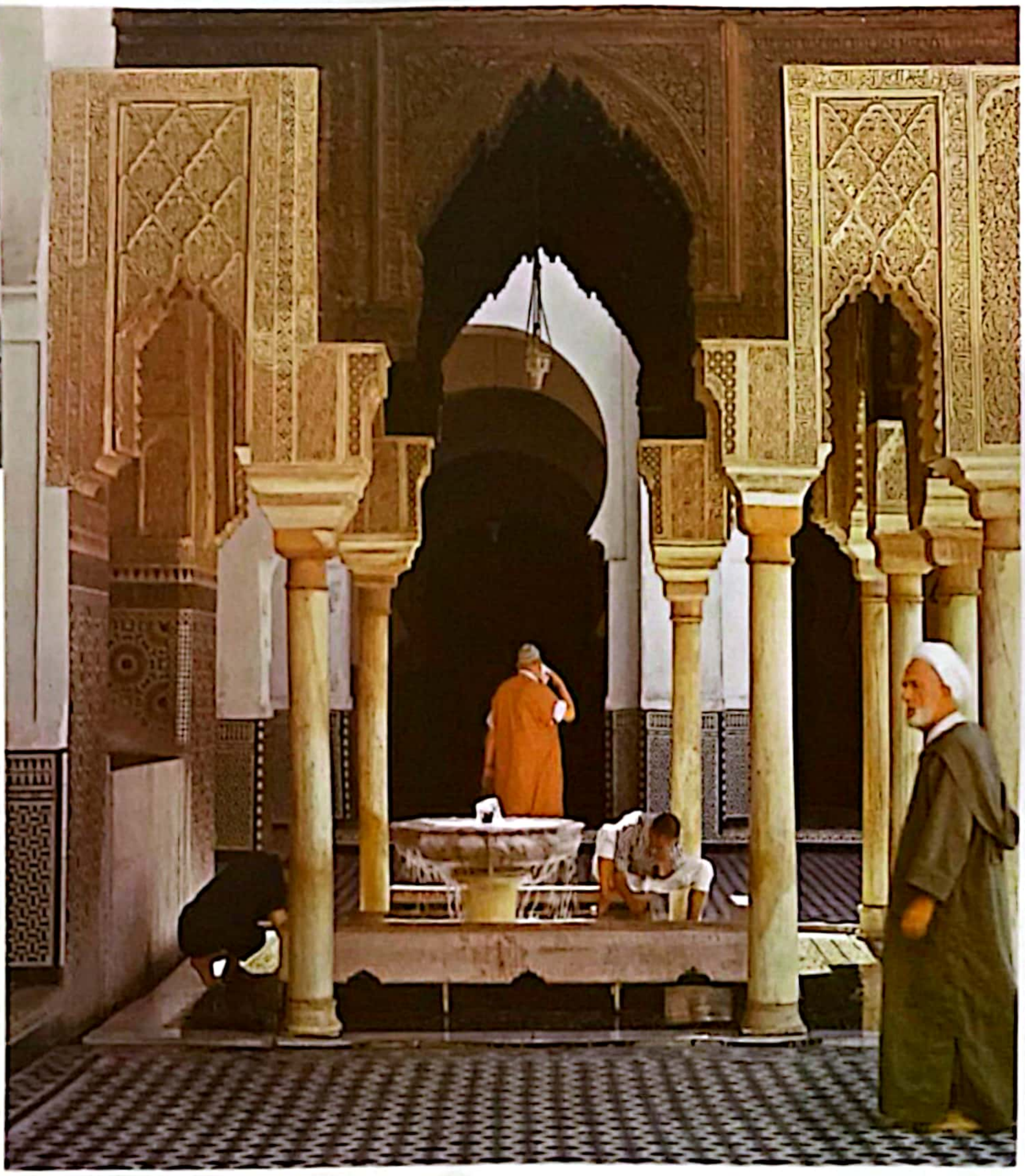
The Iranian mosque is cruciform with a domed 'kiosk' at the *qibla*. The centre of each side has a huge open porch, or *īwān*. In Isfahan (*above*) the courtyard is entered through the *īwān* on the left. To its left and right, matching *īwāns* lead to *madrasas*; the right-hand one has a complicated sundial designed by the great 17th-century mathematician, Shaykh Bahā'i. (4)

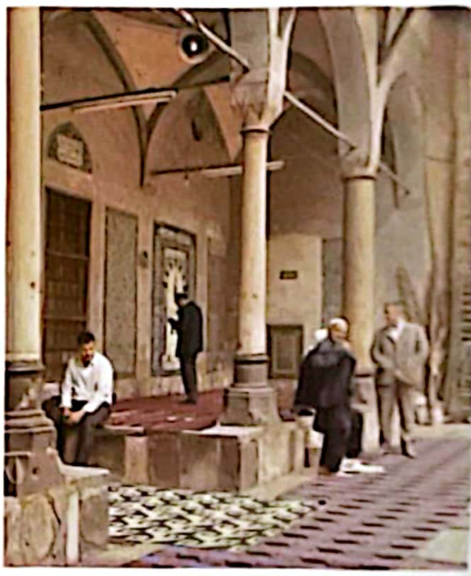
The place of community prayer, the *'īdgāh*, is a mosque reduced to its bare essentials – a great open praying area with nothing but a *qibla* wall and a *mihrāb*. Here the whole population of a city can assemble for the two major festivals, the Breaking of the Fast and the Sacrifice of Abraham. This example (*right*) is at Nizamabad, Karachi; one has mentally to ignore the modern buildings behind the wall. (5)



Entrance, courtyard and fountain

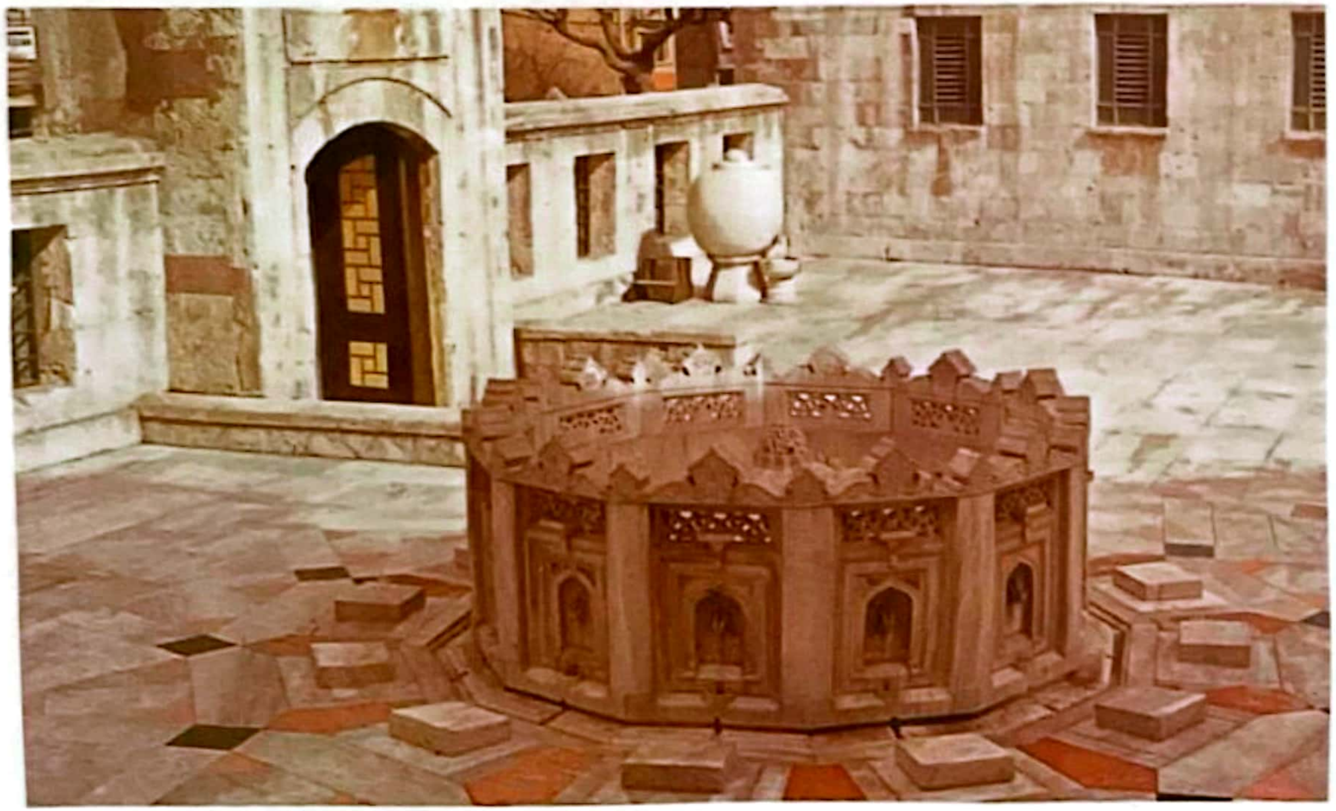
Two ancillary structures are necessary for Islamic worship: the minaret, from which the muezzin gives the call to prayer (*right*), and a fountain for ablution. The worshipper has to be in a state of ritual purity before he starts to pray. This may mean taking a bath, but normally washing certain prescribed parts of the body is sufficient. *Below*: worshippers preparing themselves for prayer outside a mosque in Fez. (6, 7)





Shoes are removed before entering the mosque. The floors are carpeted because the liturgy requires prostration, and baring the feet obviates the possibility of ritual defilement taking place. (8)

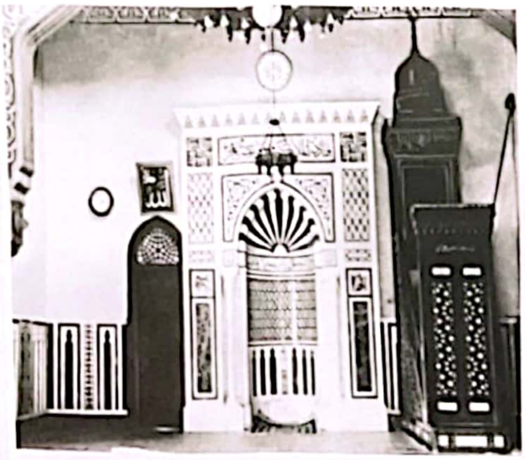
The elderly or infirm may perform their ablutions inside the mosque, using a marble jar with a basin and taps. (9)



The courtyard afforded an opportunity for architectural display, which the Ottomans, the Safavids and especially the Mughals seized with enthusiasm. In Delhi (*above*), the courtyard of the Jāmi' Masjid is surrounded by finely sculptured arches. There is an ablution tank in the middle. (10)

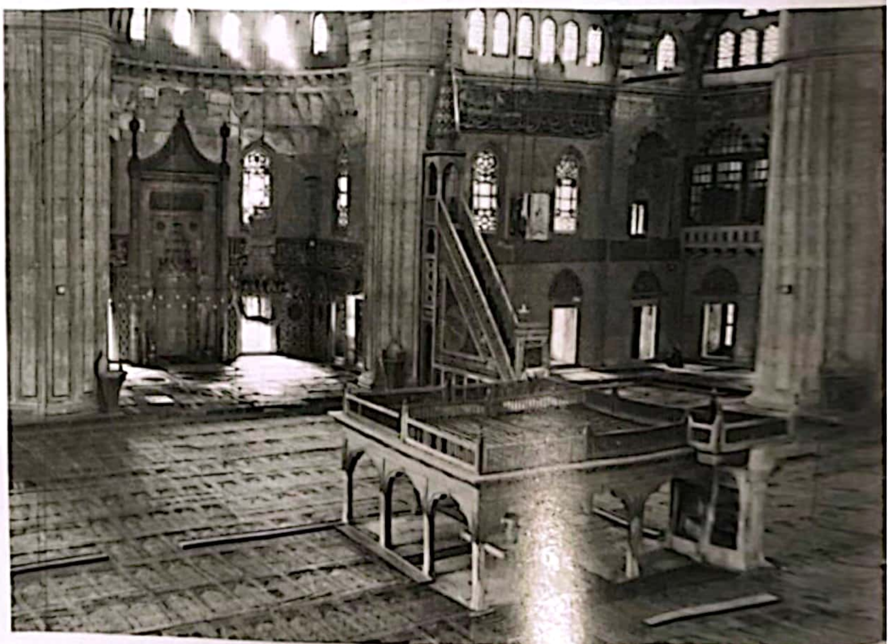
Fountains could also be works of art. In this mosque at Istanbul, each tap is set in a finely worked niche. In front are stone stools so that the worshipper can isolate himself from the ritually impure floor. (11)

The axis of prayer



Inside the mosque the chief feature is the *mihrāb*, a niche in the centre of the *qibla* wall to define the direction of Mecca. This view of the Basīlī Mosque in Alexandria (*left*) shows all the basic liturgical requirements. From left to right: a clock for regulating services, a door into the sacristy, the *mihrāb* with a prayer-mat filling the concavity, surmounted by a round window to show its position externally and with a sanctuary lamp in front of it, and the *minbar*, or pulpit. The top step of the *minbar* (*right*) is reserved for the Prophet; the *imām* stands on the second step and uses the top one as a seat. (12,13)

The masjid is distinguished from the *jāmi'*, or congregational mosque, by having no *minbar*, as in the Mosque of the Serpents, at Hama, in the Orontes Valley (*above*). (14)



The dikka [illegible]tform usually in line with the *mihrāb* [illegible]id muezzins chanting in unison the r[illegible]ses to the imām's prayers, thus transm[illegible] the particular stage of the liturgy to [illegible] out of earshot. At the Selīmiyye Mosque at Edirne (*above*), the *dikka* shelters an interior fountain. (15)

A lectern (*kursī*) for the cantor stands next to the *dikka*. In Cairo, at the mosque of Rifā'ī, it is large enough to hold a lectionary type Qur'ān. (16)

The working mosque: this lithograph by David Roberts, of the Mu'ayyad Mosque in Cairo in 1849, shows the mosque in use for teaching. The *mihrāb* is on the extreme left, with the *minbar* alongside. On the other side a teacher addresses a crowd from the high *dikka*, at the foot of which stands a *kursī*. (18)

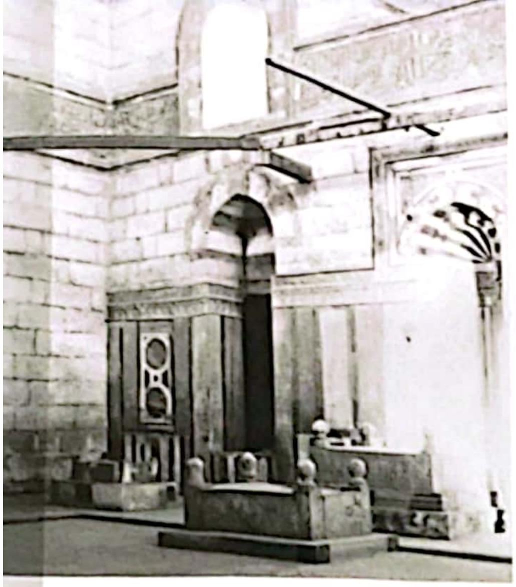
Between ritually pure and ritually impure intervenes a low barrier, glimpsed here through the door admitting to the ablution zone in the Basīlī Mosque, Alexandria (*left*). (17)

Cemeteries of Islam

Burial customs are conditioned by beliefs concerning salvation and resurrection. Bodies are placed in a recumbent position at right angles to the *qibla*, so that if turned on their right side they would face Mecca. Coffins are optional but a vault is essential, since the body must be able to sit up and reply to the Angels of the Grave.

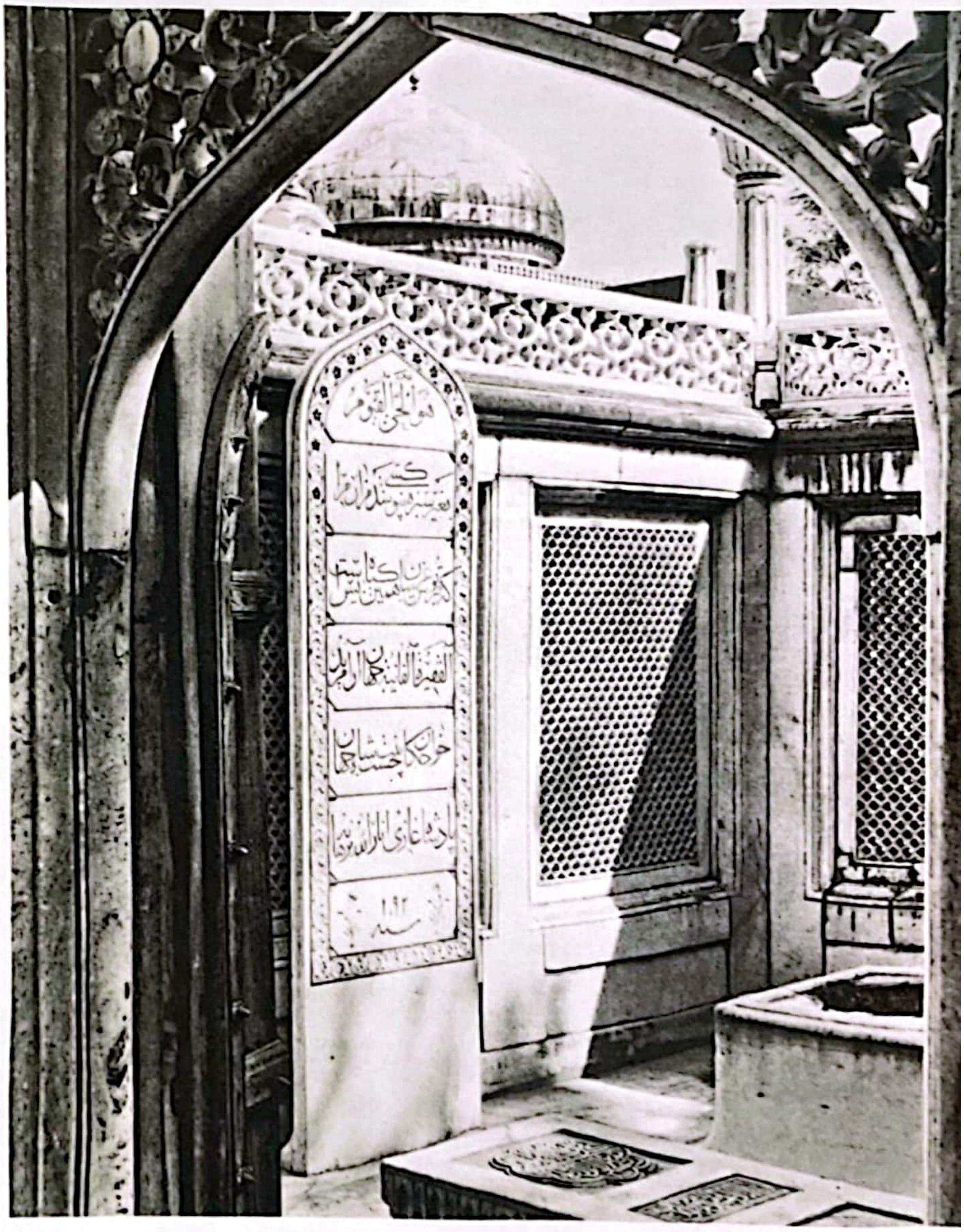
Cats were probably the Prophet's favourite animal, and enjoy special privileges in Islam. One of them appears in the manuscript on the left, and they are still a common sight in cemeteries today. (36)

A funeral procession (*left*) approaches the gate of a tomb enclosure. Professional mourners accompany the coffin, while a standard-bearer stands to one side. Inside the enclosure surrounding the tomb of a saint – identifiable by the green pall and lamp – gravediggers are lining a freshly dug grave with stones to form a vault, while masons prepare the mortar. The cat is in the upper left-hand corner. This painting is by one of Islam's greatest artists, Bihzad. (35)



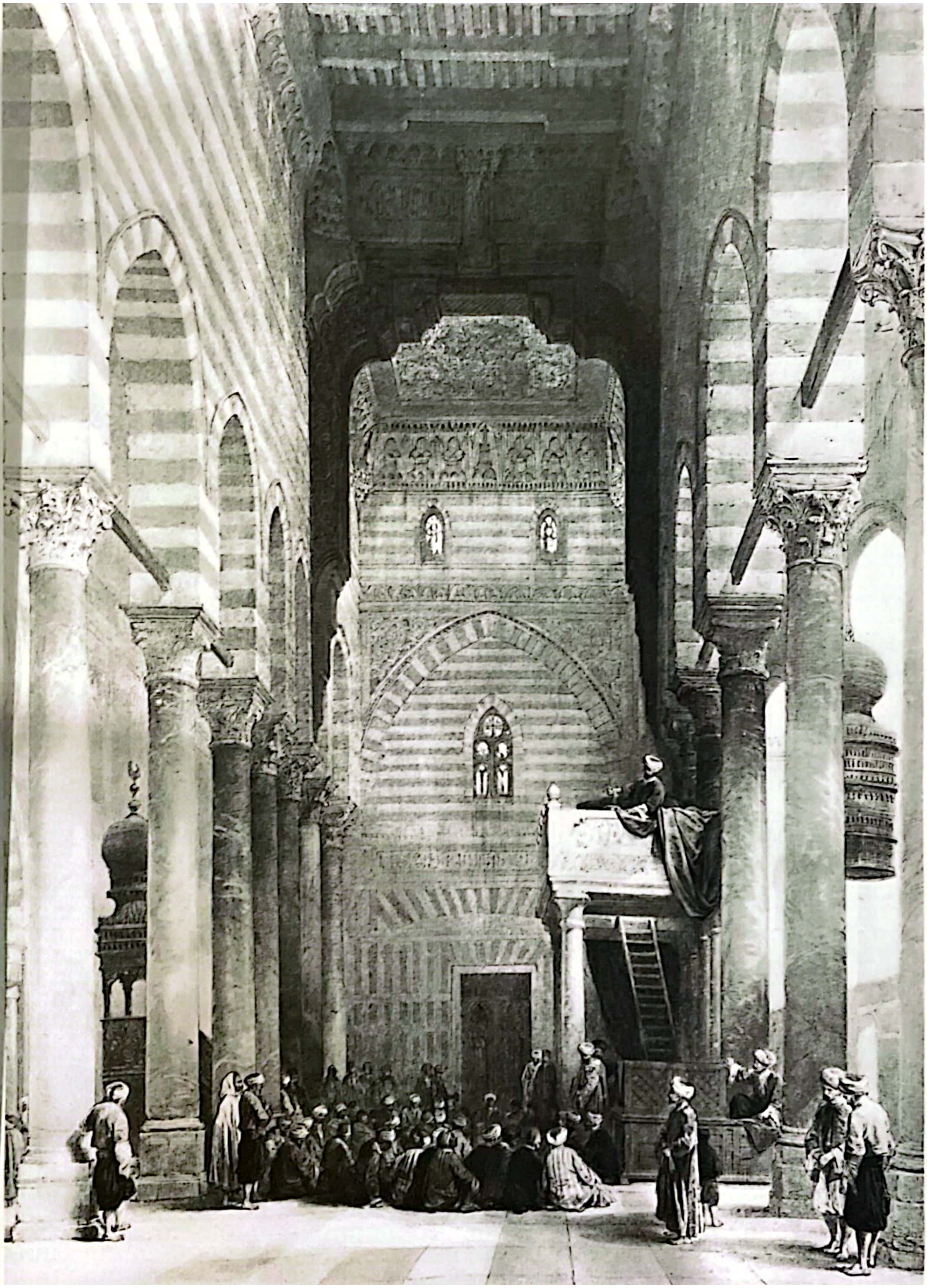
The qibla wall, being closest to Mecca, has more *baraka* than the others and tombs tend to crowd against it, leaving the centre empty. In the tomb for males in the Barqūqiyya, the exterior of which is shown in pl. 24, the graves are, as always, in the correct position at right angles to the *qibla* axis. (37)

The open sky was a fitting vault for a tomb, leaving it exposed to the blessing of rain and dew. The Köprülü tomb in the Divan Yolu in Istanbul is an example of the 'bird-cage' tomb, its beautiful bronze grille forming transparent walls. (38)



'Only the grass shall cover my grave, for grass suffices for the grave of such a pauper as I': the epitaph of the dervish princess, Jahānārā, in Delhi (*above*). One end of her earth-filled grave is seen on the right. (39)

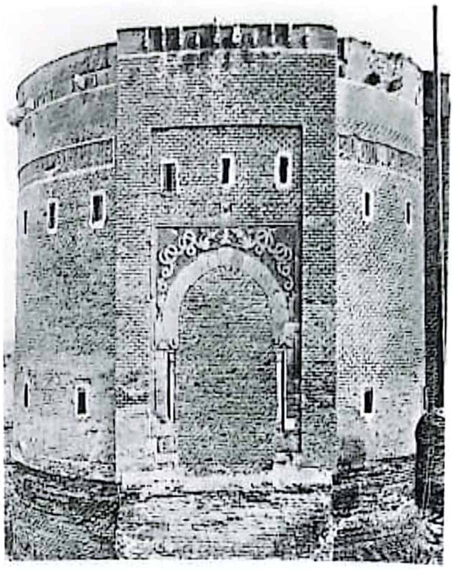
Exquisitely carved, this squat pillar (*left*) stands on the roof of Akbar's mausoleum at Sikandra to hold incense. Next to it is the imperial tomb, but it is empty; Akbar's body lies in another chamber far beneath. (40)



Gates

A gate serves to admit and to exclude. It is also a symbol – of strength, of security, of wealth.

Granada: the Gate of Justice (*left*) in the Alhambra leads through the southern wall to the palace enclosure. Carved in the keystone of the arch is an upraised hand, probably a symbol of divine protection. (2)



Baghdad: The Talisman Gate (*above*), dating from 1221, was unusual in having dragons carved above the door. When this photograph was taken it had already been walled up; it was destroyed in 1917. (3)

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Prayer and the liturgical basis of mosque design

Formal prayer in Islam consists of repeated sequences of standing, bowing, prostration and genuflection; prayer is thus not only mental and verbal but also physical, thereby involving the whole being. Behind this practice lies the central Islamic concept of God's overlordship; and the physical postures represent progressive degrees of acknowledgment of this fact, culminating in the total abasement of prostration.

Prayer is established on four levels. Firstly, the daily prayers, which may be performed in congregation but are usually carried out individually. This office is held at the five liturgical hours of dawn, noon, afternoon, sunset and evening. Secondly, the congregational prayer on Friday at noon, which replaces the noon office for that day. Thirdly, community prayer on the two major festivals, *'Īd al-Fitr* (Feast of the Breaking of the Fast) and *'Īd al-Adhā* (Feast of the Sacrifice of Abraham). Fourthly, the annual ritual of the pilgrimage, which is a congregation of all the Muslims of the world. The four levels of prayer operate on an ascending scale: firstly, the individual; secondly, any congregation; thirdly, the total population of a town or city; and lastly, the entire Muslim world. Every level except the last has a corresponding sacred structure: for the first it is a *masjid*; for the second a *jāmi'*; and for the third a *musallā*, place of prayer, or *'īdgāh*, place of *'Īd*, an immense, open praying area with nothing but a *qibla* wall with a *mihrāb* and an open-air pulpit – in other words, a mosque reduced to its essentials. The Second and Fifth Pillars of Islam interact to produce a convergence on one day in the year, which is the climax of the liturgical calendar: the anniversary of the Sacrifice of Abraham, when the climax of the pilgrimage rites in the Plain of Arafat outside Mecca coincides with the *'Īd* prayers being said throughout the Islamic world. Thus the *'Īd* ritual is a local reflection of the pilgrimage.

Just as the third level necessitated a *musallā*, so it is the second, or congregational, level which is the motivation for the mosque. And it is the congregational factor – that is, how to regulate an immense crowd in accordance with the needs of the liturgy – that entails an aetiology of mosque design to explain why each piece of liturgical furniture occupies a specific station on the floor, as well as how these pieces of furniture and the offices corresponding to them interlock to form the liturgy. Also, the morphology of the liturgical action determines what categories are embraced within a typology of mosques according to two criteria: the functional (e.g. collegiate, memorial, etc.) and the geographic or cultural (e.g. not just Iranian but Seljuq, Mongol or Tīmūrid).

The directionality of prayer is fundamental to the liturgical principles around which a mosque is constructed. A temple is a building designed to house a liturgical function. Churches developed as long, narrow buildings equipped with aisles as a result of the need to cope with a processional liturgy, whereas the mosque evolved as a square or rectangular building because it had to cope with a radial liturgy. For the architect of the mosque, two contradictory principles are involved. One of these stems from the insistence of Prophetical Tradition on the priority of the first row; that is, the first row of worshippers enjoys greater proximity to the source of blessing because it confronts the wall nearest to Mecca. There is then a *prima facie* case for extending the mosque laterally to accommodate as many as possible in the first row. But with a radial liturgy, the officiant in the middle would be invisible and inaudible at the extremities. As a result, two axes are in conflict; the primary liturgical axis of the *qibla* and the transversal axis, because of the superiority of the front row and the progressive inferiority of the rows behind. The success of a mosque architect may be measured by the degree to which he succeeds in reconciling these conflicting principles, taking into consideration the two axes and distributing mass and volume accordingly, to produce that impression of total equipoise which a successful mosque never fails to convey.

While for the daily prayers an oratory with no more than a *mihrāb* suffices or even merely a prayer-rug, which is really a portable mosque ensuring the ritual purity of the spot where the prayer is offered, there are small mosques known as *masjids*, literally, 'places of prostration', where such prayers are regularly performed behind an *imām*. A *masjid* should have no *minbar* because it is not used for Friday worship; this is the case in Turkey, where, practically alone in the Muslim world, the distinction between *masjid* and *jāmi'* is still recognized and the respective terms correctly used. The mosque par excellence, however, is the *jāmi' masjid*, that is, 'collective' or 'assembly' mosque, whose primary function is the Friday service, and hence is known in Iran as *the masjid-i Jum'a*, or Friday mosque, Friday being *Yawm al-Jum'a*, or 'Day of Assembly'. Having to cope with such numbers, and influenced by the precedent of the Prophet's Mosque (which had a covered portion supported on palm trunks), as well as the sheer expediency of utilizing the plethora of columns from redundant churches, the early *jāmi'* took the form of an immense hypostyle hall preceded by a courtyard.

Liturgical furniture of the mosque

What chiefly distinguishes the Friday service from the daily liturgy is the inclusion of a sermon. Thus, in addition to the omnipresent *mihrāb*, a *jāmi'* rejoices in the possession of a pulpit, *minbar*, to the right of the niche, so that the prayer-leader, or *imām* (properly, on this occasion an *imām khatīb*, or preaching *imām*), can address the congregation. In early Islamic times, the sermon was political rather than dogmatic in content, which helps to explain why the shape of the *minbar* has nothing in common with the Christian ambo. In origin it was the throne of the leader of the community, set up in the place of assembly, from the top of which he, Muhammad, pontificated as lawgiver. Having completed the sermon, he would descend the pulpit and enter the niche to lead the prayer, for as leader he represented the people to God and led the prayer in that capacity. This double role is expressed in the practice whereby to this day it is the same man who delivers the address as leads the prayers. The *minbar* is, therefore, a symbol of authority as much as an acoustic elevation, and in the case of the *imām*, of delegated authority. Conceivably, this may account for the fact that at a later stage of its evolution it acquired a canopy or dome, the canopy being an attribute of the ruler and even, in Indian iconography, of divinity. Moreover, the *imām* always delivers his address not from the top but from a lower step, and it may be that the empty, canopied space stands for the absent Prophet, exactly as in primitive Buddhism there was no image of the Buddha, a canopy sufficing to indicate his presence. Similarly, the practice of flanking the pulpit with standards not only emphasizes the intimate connection between politics and religion in Islam, but goes back to the Prophet, who walked to the *minbar* flanked by standard-bearers.

The first *minbar* was a rudimentary affair of three steps fashioned from tamarisk wood, from the topmost of which Muhammad addressed the Companions. Out of respect, Abū Bakr, the first caliph, occupied the intermediate step, and 'Umar modestly used the lowermost; but 'Uthmān said, 'Shall we descend into the bowels of the earth?', and thereafter everyone has used the first step from the top. During the reign of Abū Bakr, and even more with the sensational conquests of 'Umar, regional mosques proliferated, especially in the garrison towns of the Islamic armies. In these places the governor would lead the prayers, deputizing for the caliph in the same fashion as the latter deputized for the Prophet. The term *imām* survives with the meaning of prayer-leader, but as an exclusively religious office it dates only from the 'Abbāsids. Until that time, the conduct of public worship was one of the attributes of the ruler. When the governor of a province placed himself at the head of the community assembled for prayer it was clear to everyone that he was the caliph's representative. Islam does not distinguish between spiritual and temporal power. The juxtaposition of the *mihrāb* and *minbar* expresses their co-identity in the ambivalence of the *imām*, who uses both.

Pulpits are frequently of wood, richly carved and glowing with incrustation of nacre and ivory. Marble is no less common, and limestone and even iron have on occasion been used. Iran evinced a decided preference for the low pulpit, and the Indo-Pakistan subcontinent knows no other. In most countries the *minbar* became architecture in its own right, with folding doors admitting to a stairway crowned with a canopy or a bulbous cupola and topped with a crescent finial. But the most dramatic development took place in Turkey, where the stupendous Ottoman interiors required, both visually and acoustically, tall elegant structures, no less than ten metres high.

Of almost equal importance in the liturgy is the respondents' platform, or *dikka*. This usually straddles the *qibla* axis at a point about the middle of the mosque. But, since in a radial liturgy the first prerequisite is the visibility of the officiant in his niche, the *dikka* can also be positioned off the axis to the right. Although resorted to frequently in Turkey, this measure sensibly reduces the efficacy of the *dikka*. It is another prerequisite, not so much the visiblity of the *imām* as the audibility of his voice, that forms the *raison d'être* of the *dikka*. The *dikka* is a very early innovation and was already in widespread use by the 8th century, increase in congregation size having decreed its invention. Its closest approximation, outside Islam, is the choir stalls of a church. The respondents are known as *muballighūn*, human amplifiers (of the *imām's* voice), but it is not an office in its own right, for in a mosque every muezzin doubles as a respondent. Their function, from their vantage point atop the elevation of the *dikka*, is to copy the posture of the *imām* and chant in unison the appropriate exclamation or response, thereby transmitting that stage of the liturgy to the ranks behind, for whom the *imām* is neither visible nor audible. To regulate the movement of the congregation, liturgical signals are used, the most important being the *takbīr*, or Magnification, *Allāhu akbar*; and the importance of the *muballighūn* lies in the fact that by means of these signals they co-ordinate and synchronize the movements of all parts of the congregation.

With the advent of the loudspeaker, platform and respondents alike fell into desuetude, at which point Islam embarked on its present course of liturgical decadence. Their function was absorbed into that of the *qāri'*, or cantor, whose lectern flanked the *dikka*. Known as *kursī 's-sūra*, 'chair of the *sūra*' – because from it the cantor chants the Eighteenth Sūra of the Qur'ān in the half hour that elapses between the first and second *adhāns* – this is the last item of liturgical furniture to be considered. The art of *tajwīd*, or cantillation of the Qur'ān, is one of the most cultivated arts in Islam, being the phonic equivalent of calligraphy, the Islamic art par excellence. Most mosques have always had at least one lectern, or *kursī*. In Egypt the earliest-dated *dikka* bears the name of the 15th-century ruler, Qāyitbāy, but the earliest *kursī* goes back to Fātimid times (in the mosque within St Catherine's Monastery, Sinai). Like the earliest *minbars* (which ran on wheels), the *kursī* is a moveable item of furniture, albeit ponderous and awkward to shift. Made of wood with the habitual lavish incrustation, the standard *kursī* incorporates a little platform on which the cantor kneels facing the *qibla* as well as, optionally, a V-shaped slot to hold a copy of the Qur'ān. Mosque Qur'āns are gigantic and are comparable to lectionaries and antiphonaries, sometimes requiring two men to carry a single tome of a thirty-volume Qur'ān. Cantors are assigned in greater numbers to colleges and mausolea: in the former case so that students may learn the approved methods of reading the Qur'ān, and in the latter so that the deceased may benefit from the *baraka*, or spiritual power that inheres in the words.

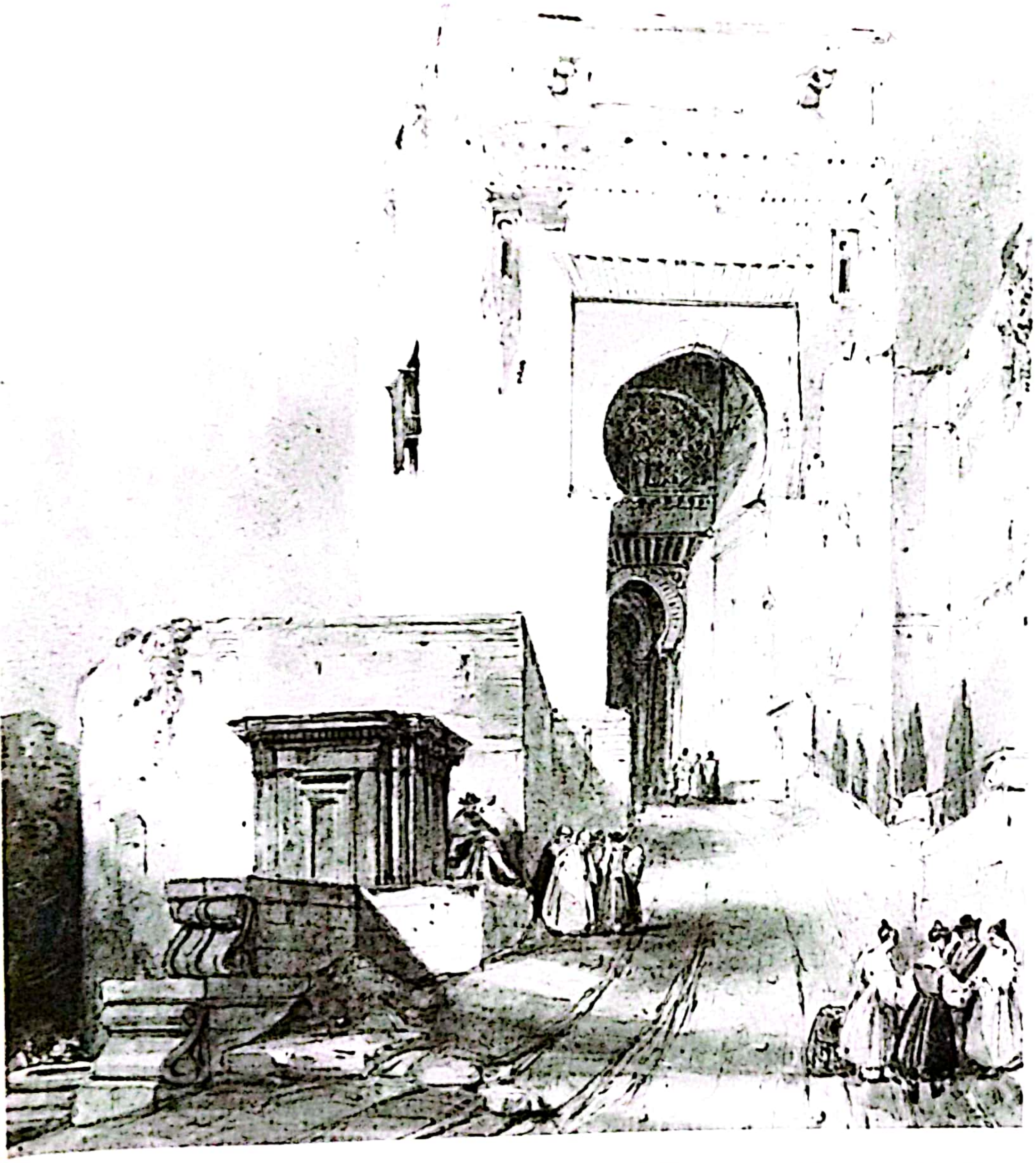
In addition to niche, pulpit, respondents' tribune and cantor's lectern, a mosque abounds in quasi-liturgical items, such as folding stools to keep the Qur'ān off the floor, out of respect; safe receptacles, known as *kursīs*, used for holding the Qur'ān; reliquaries; sanctuary lamps; another, but differently shaped, *kursī* for instruction; and prayer-rugs, either single or serial; as well as candlesticks which flank the *mihrāb*, and which when lit during Ramadān envelop the *qibla* in an atmosphere of cultus. But all these count more as furnishing than furniture and command no place in the liturgy comparable to the intermeshing functions of *mihrāb*, *kursī* and *dikka*. The latter in pre-electronic mosques now stands forlorn, lamentable to behold, while in the modern mosque it does not even exist. Its abolition, with consequent dislocation of the *kursī* due to the development of electronics, has been a catastrophe, for it entails a loss of the stereophonic character of the liturgy. St Augustine wrote that architecture and music were the highest arts because they were 'the sisters of numbers', an admission which shows he was a Pythagorean at heart. The aesthetic significance of the mosque resides not in the architecture alone but in the fact that it was a place where that art was always to be found in the company of its sister.

The collegiate mosque, or madrasa

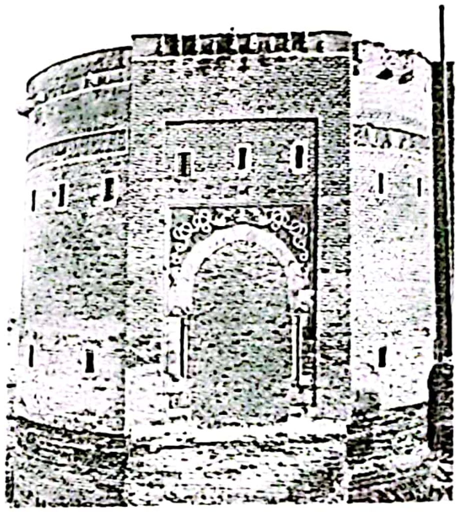
The functional criterion applied to a typology of mosques yields, in addition to separate structures for daily, congregational and community prayers, such other types as memorial, tomb, shrine and cemetery mosques as well as the monastic mosque, and one other

Gates

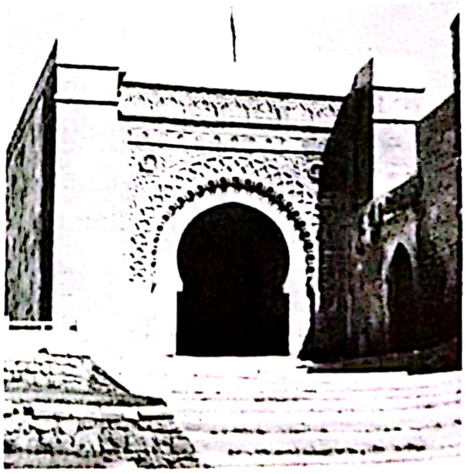
A gate serves to admit and to exclude. It is also a symbol – of strength, of security, of wealth.



Granada: the Gate of Justice (*left*) in the Alhambra leads through the southern wall to the palace enclosure. Carved in the keystone of the arch is an upraised hand, probably a symbol of divine protection. (2)



Baghdad: The Talisman Gate (*above*), dating from 1221, was unusual in having dragons carved above the door. When this photograph was taken it had already been walled up; it was destroyed in 1917. (3)



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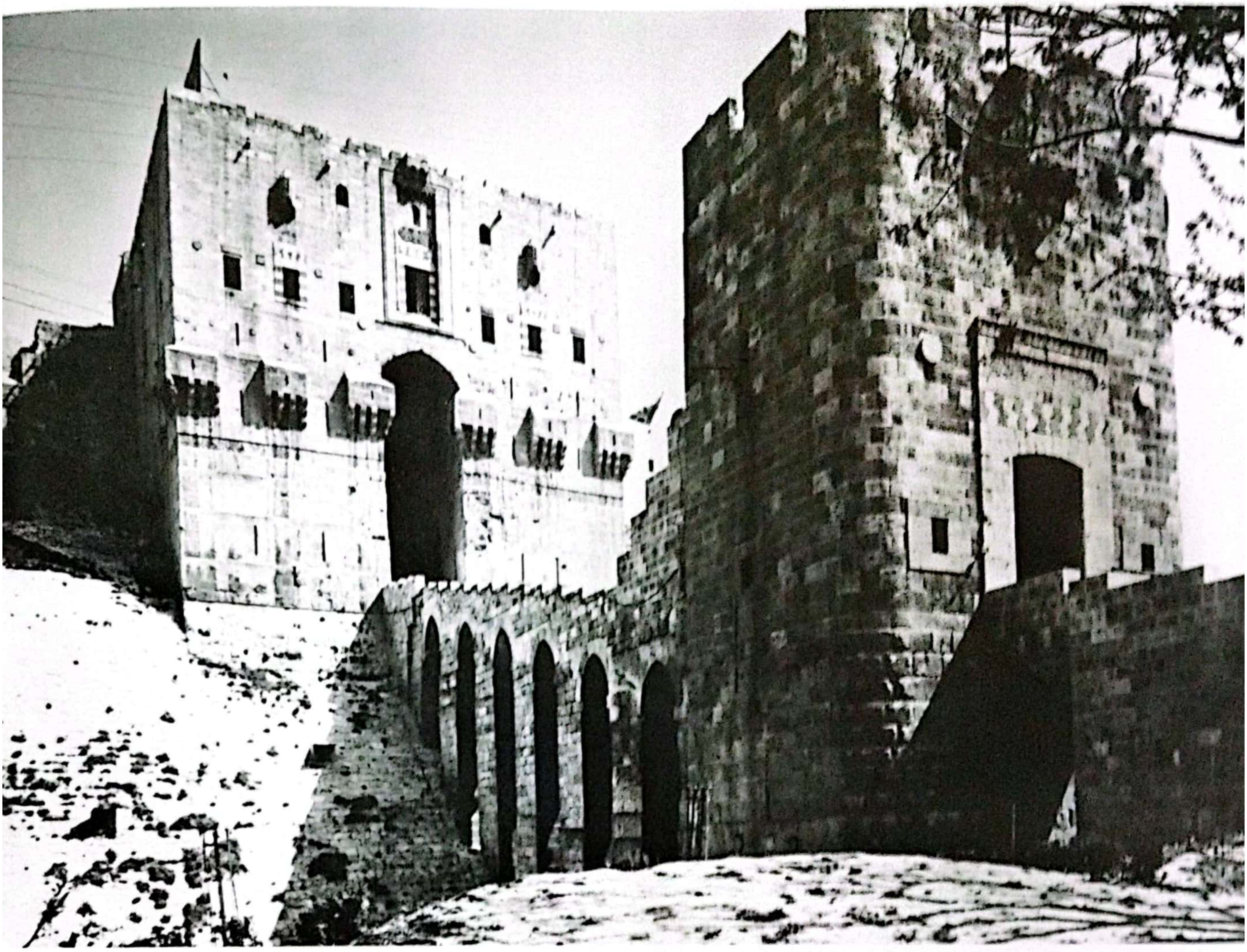
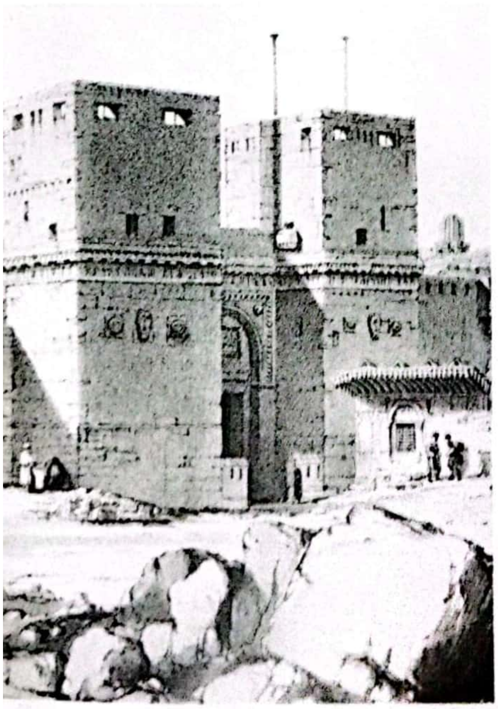


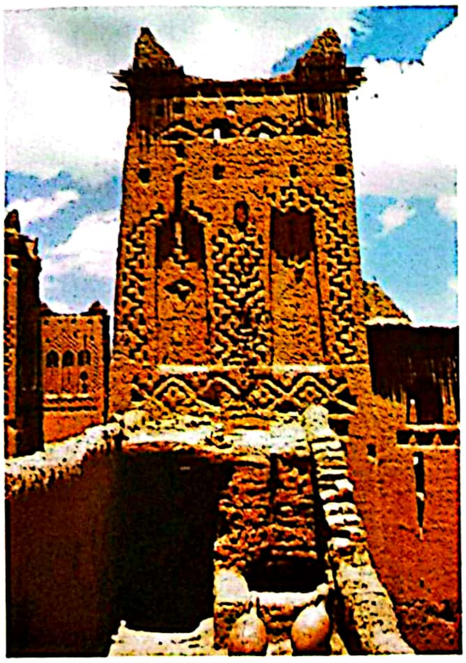
Aleppo: the double gates of the citadel (*above*), connected by a bridge over a moat, proclaim impregnable strength. (6)



Cairo is among the best preserved of Islamic cities and several of its ancient gates are intact. The Gate of God's Help (*left*) and the Gate of Conquests (*right*) were both built in the 11th century to traditional designs – basically straight passageways with heavy doors – and differ only in the shape of their towers. Above the first is carved the Muslim profession of faith in *kūfī* letters and an inscription giving the date, 1087. (7,8)

Walls and towers

Military architecture is the most direct expression of power. At Diyarbakır (*opposite*), inscriptions and sculpture also reinforce the physical strength of its black basalt walls.(9)



Skoura in Morocco (*above*) and **Baku** in Soviet Azerbaydzhan (*below*) show how regional variations diversify what is basically the same architectural form. Brick patterning softens the severity of many North African buildings, while the citadel at Baku contained an open pavilion behind its lowering ramparts. (10,11)

From Yazd in Iran (*top*) to **Rumeli Hisar** on the Bosphorus (*bottom*), the type of defensive work with crenellated walls punctuated by towers remained standard. The walls of Yazd go back to the 14th century; they surround a desert city in an oasis, dependent for water on miles of underground conduits. Rumeli Hisar, by contrast, approaches more nearly a European *château-fort*; it was built as part of the Ottoman defence of Istanbul and already takes account of new developments in artillery. (12,13)

Walls and towers

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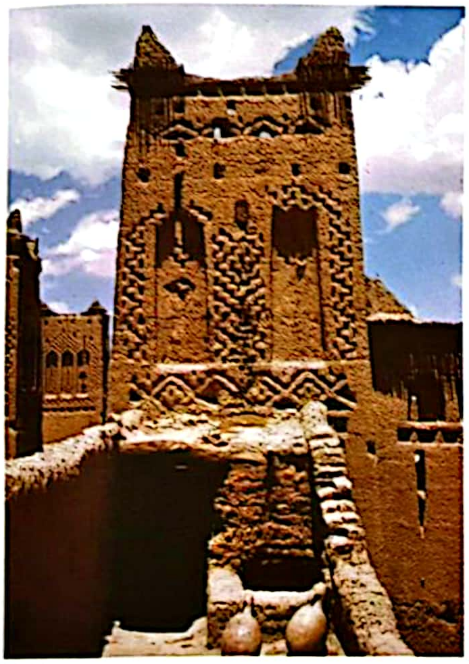

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Walls and towers: As early as the 9th century the complex of cities known as Raqqa, on the Euphrates in Syria, was provided with a fortified enclosure. The walls of the present-day city of Raqqa, massive mud-brick constructions preceded by a moat, may indeed be remnants of early 'Abbāsid walls, although their exact date still requires archaeological investigation. But the still unexplored circular city of Hiraqla, to the north of modern Raqqa, may in fact be a creation of Hārūn al-Rashīd and, as air photographs and cursory ground surveys show, it was provided with impressive walls. It is still uncertain whether the presence of defensive walls at Raqqa was the result of the direct impact of the capital Baghdad, of the fact that one of Raqqa's functions was to be an assembly point for military expeditions against Byzantium, of attempts to protect it against nomadic incursions, or of the proximity of Classical and Byzantine fortified cities in what used to be a frontier area before Islam. Arguments exist for any one of these interpretations but a positive answer requires additional literary and archaeological investigations.

No such problem of interpretation exists for cities after the 10th century. Hardly a town of any significance existed without fortified walls, mighty towers, and elaborate gates – often new ones, as in Herat, Yazd, or Damascus, but frequently totally or partially refurbished pre-Islamic ones, as in Jerusalem or Istanbul. From a purely architectural point of view not much can be said about these walls and towers. Mostly they are massive constructions built in materials characteristic of the region in which they are found: unbaked brick or packed earth in eastern Iran, stone in Syria and Palestine, various mixtures of brick and stone in Spain. Round, square, or elongated towers served as buttresses, lodgings, arsenals, or whatever other military purpose may have been required. Crenellations, walkways, machicolations, and, occasionally, small protective cupolas at key intersections of walls were probably stock elements in the construction of most of these walls and towers. But, although there are instances of major changes in wall construction – as in the switch from brick to stone in 11th-century Egypt or in the bewildering masonry types found on the walls of Jerusalem – the purely defensive military walls of Islamic architecture are on the whole hardly novel or original, even if at times, as in the walls of Diyarbakir, the Alhambra, or the much later Iranian city of Bam, they are quite spectacular.

Gates: Matters are more complicated when we turn to gates. Two types of plan predominate: the straight gate, which was primarily a passageway even when provided with massive doors; and the bent entrance, which has obvious defensive uses, becoming in a few instances, such as the Gate of Justice in the Alhambra, a double bent gate. Both types of gates have a long pre-Islamic history and, although the bent gate became more common in obviously military architecture and in the western parts of the Muslim world, both tended to be used quite indiscriminately, especially in later centuries.

More interesting aspects of gates are their construction, their decoration, and the names given to them. Because they are so frequently dated, gates are one of our best examples for the history and development of vaults. For instance, in 11th-century Cairo or 14th century Granada the gates were built with an unusual number of different techniques of vaulting. Squinches coexist with pendentives, barrel vaults with cross vaults, simple semicircular arches with pointed or horseshoe arches. Gates can serve as a sort of gauge of the most common construction techniques and easily available materials of any one time. This is particularly so in areas where stone predominated, as baked brick was less frequently used in large-scale military monuments or has not been as well preserved. It is even possible that certain innovations in Islamic vaulting techniques, especially the elaboration of squinches and of cross vaults, were the direct result of the importance of military architecture, for which strength and the prevention of fires, so common in wooden roofs and ceilings, were major objectives.

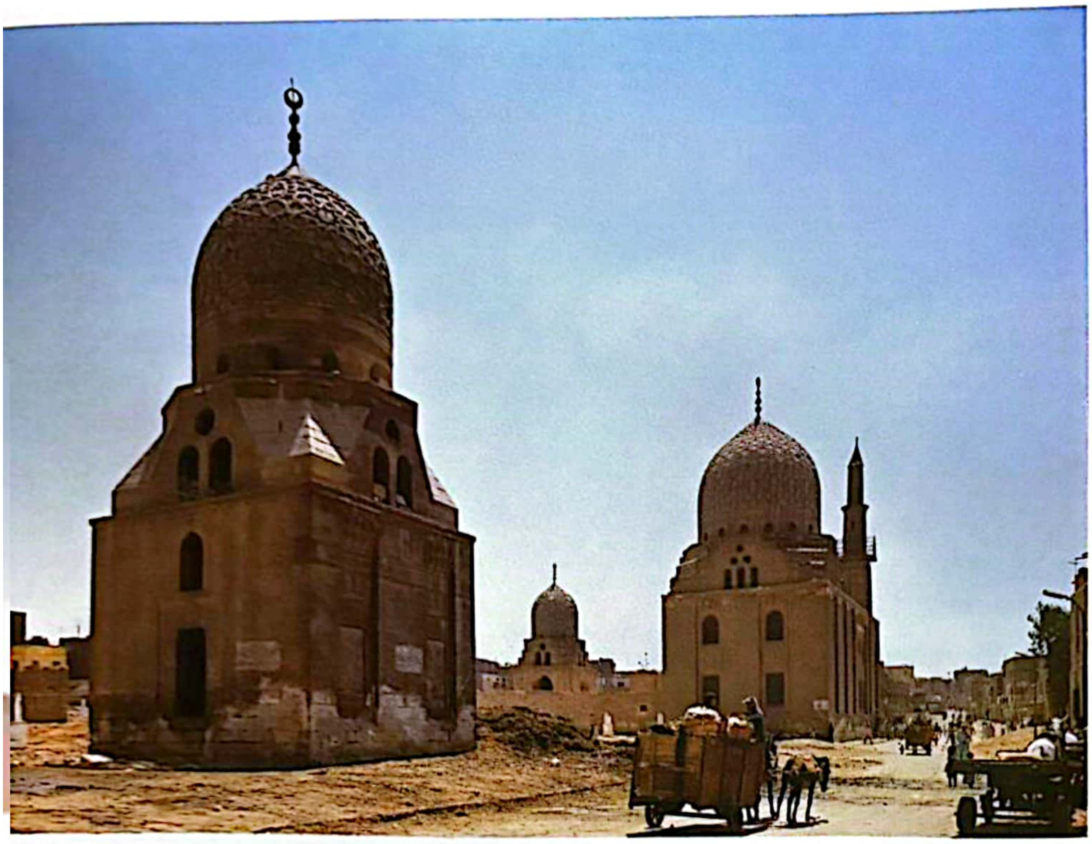
The decoration of gates is tied to the broader question of the symbolism of gates. Certain official city gates did acquire symbolic associations and, as we shall see, were provided with appropriate visual expressions. Whether the more common and purely defensive gates were similarly decorated is a moot point. There is the evidence of the animal sculptures on the gates of Diyarbakir or on St Stephen's Gate in Jerusalem, for both of which it is possible to suggest either a magic meaning of protection or a symbolic meaning of the sovereignty of individual princes. A few literary references on early Islamic Isfahan tantalizingly suggest the possibility of astrological symbolism, and there is little doubt that further searches in written sources will yield additional examples of the same sort. But there does not seem to be a clear and consistent pattern to a visual symbolism of purely defensive gates in Islamic lands and each exception should be seen and explained independently.

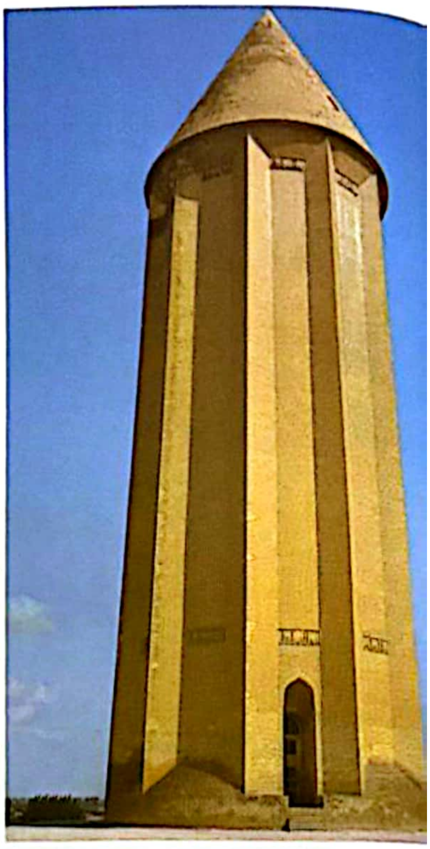
A similar question concerns the names of gates, and is answered in a similar manner. Most names are topographical, involving either the local characteristics of a city or of its suburbs (Gate of Tanners or of whatever tribe settled nearby, as occurs in Marrakesh), or the nearest major centre (Jaffa Gate in Jerusalem). Sometimes there are references to real or mythical events associated with the gate, as occur in some examples in Jerusalem. Most of these are once again unique instances. But many more cities had a *bāb al-sirr*, a secret gate, possibly simply the means by which an army could easily leave or enter a city, rather than the gate of betrayal as some have interpreted it. A consistent name of gates is the Gate of the Lion, and it is true that on city gates in Derbend in the Caucasus or in Hamadan in Iran there seem to have been reused ancient sculptures of lions. It is, however, still difficult to determine whether these examples had a consistent and fully developed symbolic value at all levels, and not merely at a popular one.

Citadels: A more original development of Islamic military architecture is the citadel, *qal'a*, *kuhandiz*, or, more frequently in the western Islamic world, *qasaba*. A fortified defensive unit, occupied by a king or by a feudal lord and located in an urban centre, is of course not a new development, for it is found in ancient Assyrian cities like Khorsabad, and probably from that time onwards it became the typical landmark of most Near Eastern cities. In all likelihood the Arabs took over existing citadels in the areas they conquered, but it is only in north-eastern Iran that the literary evidence is clear on this point, perhaps because citadels were more common there in pre-Islamic times than elsewhere in the Middle East. We shall see later on that another type of government building appeared in western and central provinces of the empire. As the authority of the caliphate declined and the Turkish military became the main, if not the exclusive, ruling force in most of the Muslim world, old citadels were refurbished, for instance, in Jerusalem or Aleppo, and new ones were built, in Cairo and probably Damascus. Beginning in the 10th or 11th centuries, practically every town of any importance from Transoxiana, for which we have the geographer Ibn Hawqal's description of Bukhara's citadel, to Egypt, even including many secondary cities such as Homs in Syria or Hisn Kayfa in Turkey, acquired seats of power. These took the form of a forbidding, fortified area, usually built astride the city's walls, but sometimes tucked away in a commanding corner of the city or, much more rarely, situated outside the city. The most spectacular and best preserved of these citadels is the one in Aleppo, located on a partly natural and partly artificial mound overlooking the whole town. A superb stone glacis emphasizes the height of the monument, which can only be reached through a handsome bridge over a moat. Inside, ornate, formal audience halls adjoin mosques, baths, living quarters, even a religious sanctuary dedicated to Abraham, cisterns, granaries, and prisons. There is something very haphazard about the internal arrangements of Aleppo's citadel, possibly because of the rugged requirements of the terrain, but also because there was no set plan for citadels, nothing comparable to the formal order of Roman camps for instance, and Aleppo's citadel grew according to the whims of individual local rulers.

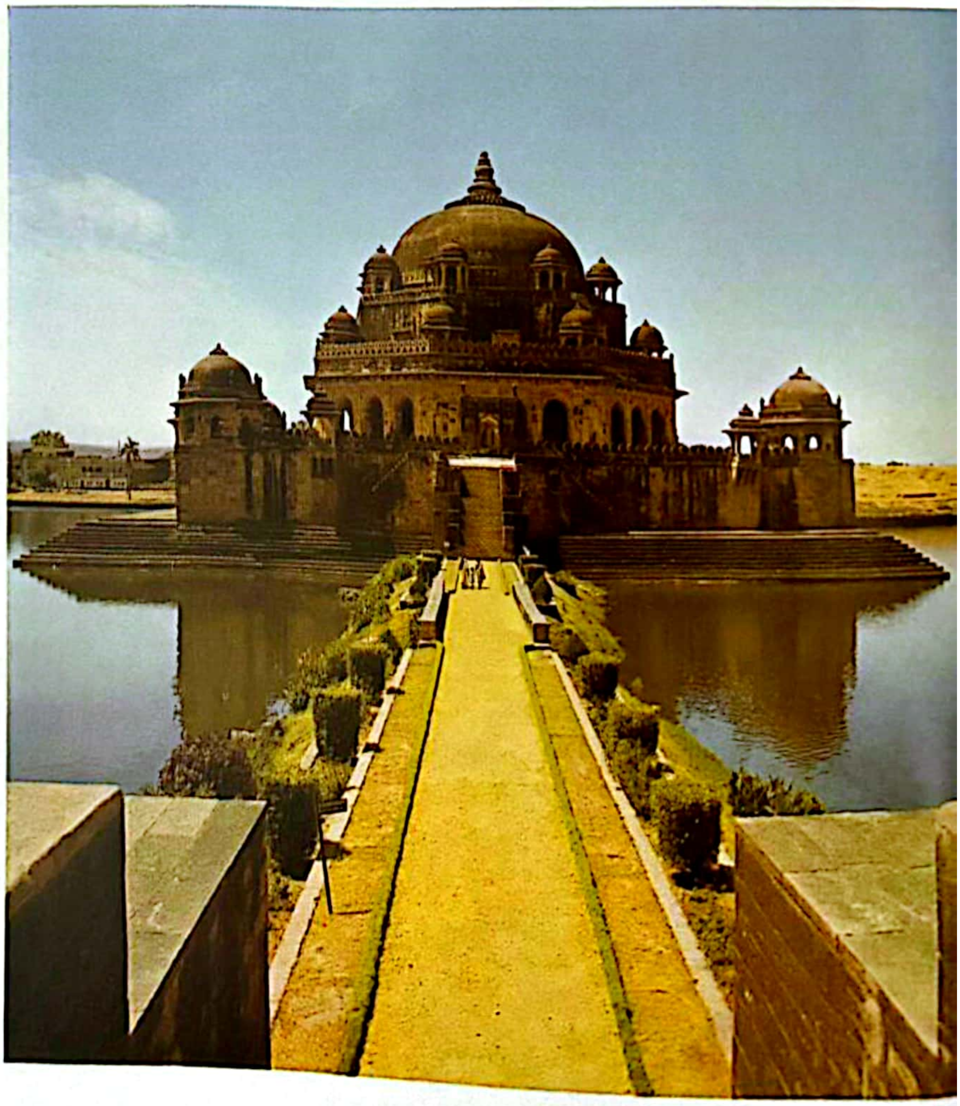
Few citadels are as impressive as Aleppo's, but most of them were located in such a fashion that both practically and symbolically they dominated the urban centres that they controlled. Interior organization varied enormously. The Alhambra, in addition to the celebrated palaces, was originally a whole city with houses, a mosque, baths, and other amenities normally required by an urban system. Ibn Hawqal describes Bukhara in the same manner, as a small city. The Cairo citadel included several palaces and mosques, and the citadel of the Shīrvān-Shāhs in Baku contained a unique open pavilion more typical of garden palaces than of defence monuments. Other citadels, the one in Damascus for instance, were more exclusively military, with barracks, arsenals, granaries, jails, a small oratory, and occasionally a slightly more formal apartment or reception area.

The variations in size and importance complicate any attempt to define the architecture of citadels as a whole. Another factor is that all of them have been so frequently modified over the centuries (many are still used today for purposes akin to their original ones) that elaborate archaeological investigations are needed before we can properly understand the character of their original constructions and the changes that were introduced. It can be hypothesized that, initially, citadels were strictly military, serving to accommodate alien soldiery away from the city's population. The reason why so many early citadels are found in Iran, especially in the eastern provinces, may be that in these areas of limited Arab presence it was particularly important to maintain the contrast between conquerors and conquered during the first centuries of Muslim rule. As the version of feudalism peculiar to Islam developed and as local dynasties were founded, some amenities of life were introduced into citadels, as well as official reception halls and other symbols of





Outliving death, the power and glory of Muslim rulers was given public expression in a series of magnificent tombs. Despite a lack of orthodox religious sanction, these tombs are characteristic of virtually all Islamic dynasties. In **Cairo**, the Qarāfa cemetery (*above*) is a competitive display of family wealth. The **Gunbad-i Qābūs** ('Dome of Qābūs'), near Gorgan in Iran (*upper right*), was built by this local ruler in 1006 to house his remains and commemorate his name. In the second objective he succeeded, but his body, which is said to have been suspended in a coffin some 50 metres above the ground, has long since disappeared. (20,21)



At Sasaram, India, stands the mausoleum of Shīr Shāh Sūr, an Afghan who temporarily ousted the Mughals between 1540 and 1545. Less famous than the Tāj Mahal, it is nevertheless its rival in dignity and monumental effect. The dome, reflected like that of the Tāj in an artificial lake, rises more than 50 metres above the water. (22)

Soltaniyeh was founded by the Mongol rulers of Iran early in the 14th century and was for a brief period their capital. Like many greater cities, including Baghdad and Cairo, it is an example of an entire city conceived as an expression of the monarch's power, and was originally intended as a centre of pilgrimage. Most of its glories have disappeared, leaving only this vast mausoleum of Öljeytu, who died in 1316. Dominating the village sited on the remains of his once remarkable city, Öljeytu's tomb still suggests past splendours, when its eight minarets encircled the huge pointed dome covered in blue glazed tiles. (23)

A high point of Islamic bridge-building is reached in the famous Khwajū bridge at Isfahan, where functional and aesthetic considerations are effortlessly combined. The central roadway is flanked by arcaded galleries for walking or standing and chatting. When the water is low, people can also sit and picnic on the stepped cut-waters. (11)

At Dezful, in Iran (*right*), the road ran across the top of a dam built on Sasanian stone foundations. Behind it an artificial lake fed irrigation channels. (12)

Markets

A settled hierarchy governs the layout of Muslim markets, and is surprisingly constant from North Africa to India. Food-stuffs are generally sold in the open air, as in this example at Rissani, Morocco. (27)

The cloth market: detail from a Mughal miniature of the 17th century. (28)

The standard bazaar plan is a network of streets (*sūqs*) covered with vaults and domes, often with higher domed or open areas at the crossing-points. In Central Asia, the market may be enclosed by a wall, as in Bukhara (*below*), where the wall was recently rebuilt. (29)

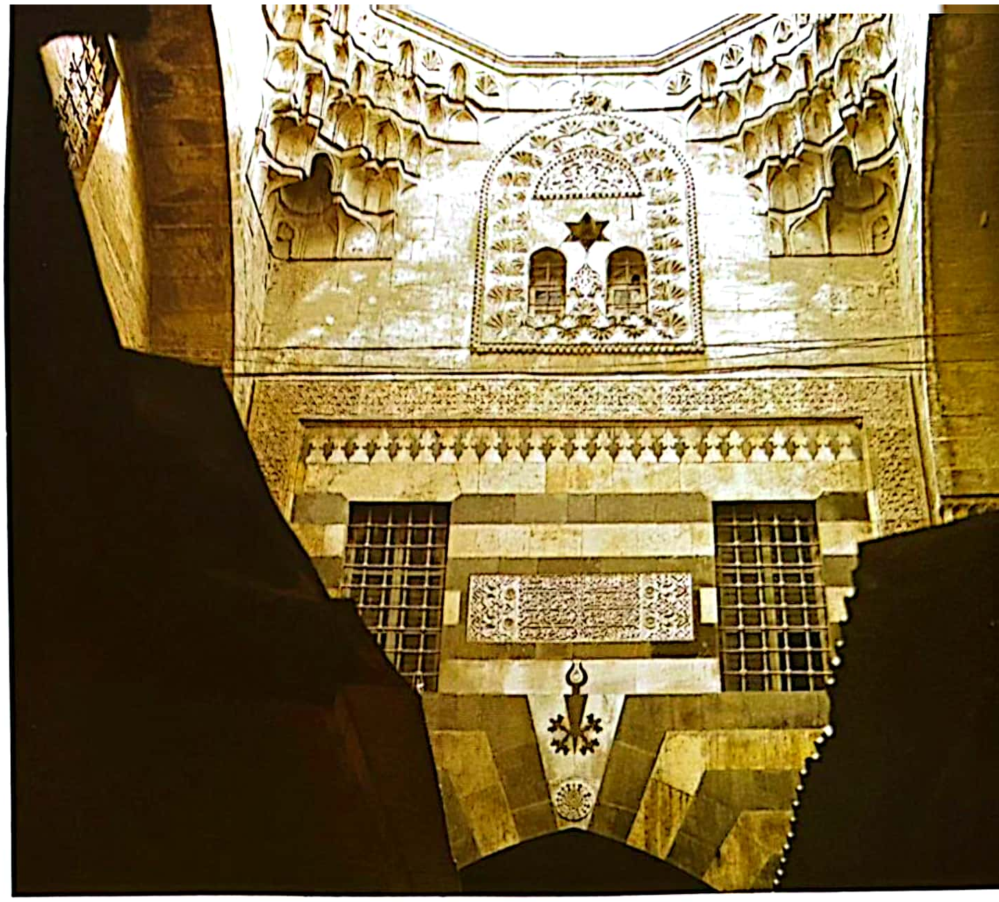
Bazaar and bath

Bazaar and mosque grew together, the twin poles of Islamic urban life, separate but in harmony. This remains true even at a local level, as in this small bazaar at Qazvin, Iran (*above left*). *Above right:* books and spices for sale in the *sūq* at Kashan. Grandest of all the Ottoman bazaars is that of Istanbul (*below*), at whose centre rise the two multi-domed sections of the *bedesten*, where the most precious goods were sold. (33, 34, 35)

Bridges

Muslim roads often followed pre-Islamic routes, and Muslim bridge-building techniques are based on Roman or Sasanian precedents. Primitive structures can be seen today in remote areas like Afghanistan (*left*). Among the most impressive are those of Seljuq Anatolia, where the Roman prototype is modified by raising and widening the central arch. *Below:* the stone bridge over the Köprüçay River, between Antalya and Alanya in Turkey. Other functions tended to congregate near bridges; the building to the left is a caravanserai. When the bridge at Jaunpur (*bottom*) was built, between 1564 and 1574, pavilions were added for tea-houses, and in time it became the venue for a market. (8, 9, 10)

The bazaar is one of the classic defining features of an Islamic town, the commercial 'spine' of the urban fabric linking mosques, *hammāms*, *khāns* and schools – a city in miniature, consisting of dozens of streets, sometimes intersecting at right angles. Shops selling the same goods are always grouped together, so that there will be a spice bazaar, a leather bazaar, a metalwork bazaar. The plan of Aleppo market is reproduced and explained on p. 108. Where the main streets cross, the large spaces are either domed or open to the sky. One such crossing in Aleppo (*right*) is given elaborate *muqarnas* decoration. (31)



Each shop occupies one compartment in the *sūq*. This part of the carpet section is in the bazaar at Tripoli, Libya. Every available wall surface is used for displaying goods. (30)

The vaulted streets are lit by apertures in the centre of each bay, creating a cool and well ventilated space that is ideal for hot climates. Essentially the same architectural form prevails over the whole Islamic world; a typical interior, such as that of the Aleppo bazaar (*right*), is roofed in a procession of domes. (32)

15 SOARING FACTS

❶ Since the beginning of time every civilization has seen **birds flying** and **dreamed of taking flight themselves.**

❷ The Muslim civilization's **fascination with flight** was reinforced by the belief that when the human soul reaches the highest level of goodness it **rises above the Earth.**

❸ In his *Book of Kings*, Persian poet Al-Firdawsi recounted the tale of King Kai Kawus, who was tempted by evil spirits to invade heaven on a flying throne. **The eagles carrying him grew tired, and he crashed.**

❹ In 852 a Spanish Muslim named 'Abbas ibn Firnas made an early **parachute jump when he leaped** off the Great Mosque of Córdoba (Spain) **wearing a reinforced cloak.**

❺ **Twenty-three years later,** 65-year-old Ibn Firnas made the first controlled flight using what **we would call a hang glider.**

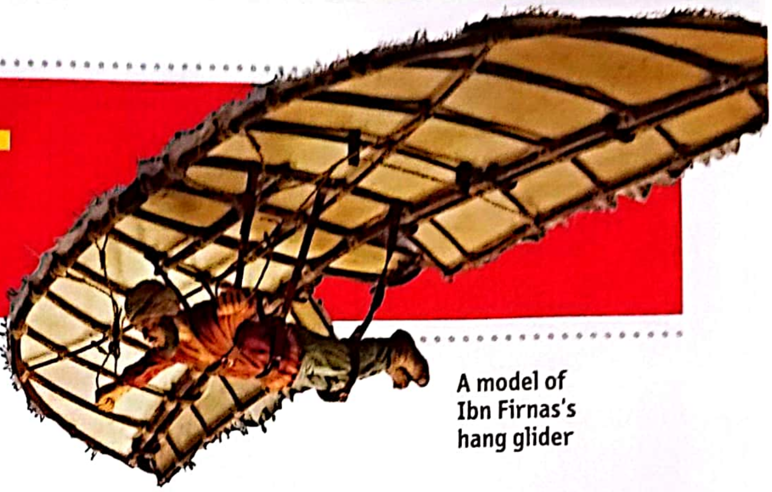
❻ Ibn Firnas's hang glider resembled **a bird costume made of silk and covered with eagle feathers.**

❼ The story goes that Ibn Firnas **hung in the air for more than ten minutes** using his glider before crashing to the ground.

❽ The **rough landing** made the flight pioneer realize the important role a bird's tail plays in a safe landing. **Today all planes touch down with rear wheels first.**

Chinese red dragon kite

ON FLIGHT



A model of Ibn Firnas's hang glider

9 Leonardo da Vinci made his **famous drawings of birdlike flying machines** almost seven centuries after 'Abbas ibn Firnas's experiments with flight.

10 In the 17th century, a Turk named Hazarfen Ahmed Celebi **used an eagle-feathered glider** to fly across **the Bosporus**, a strait that flows through **Istanbul, Turkey.**

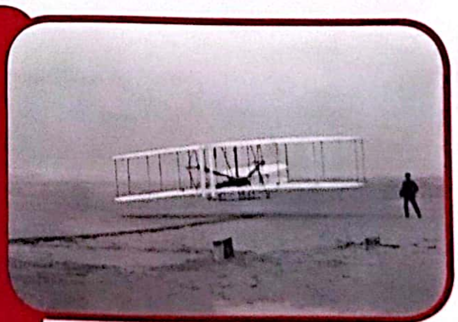
11 In 1971 a Turkish **postage stamp** was created to honor Hazarfen Ahmed Celebi's **famous flight.**

12 **Great snipes** hold the record for the fastest long-distance, nonstop flight of **any living bird.**

13 The **first manned rocket** was said to have been invented by Lagari Hasan Celebi in 1633.

14 Lagari Hasan Celebi's **gunpowder-fueled rocket** carried him **high into the sky,** where he spread out wings and glided down before plunging into the water. For his risky flight Celebi was **rewarded with a pouch of gold** from the Sultan.

15 **Birds also influenced the thinking of the Wright brothers,** whose successful flight in 1903 paved the way for **modern aviation.**



1

A THOUSAND YEARS BEFORE EUROPEANS MADE SIGNIFICANT ADVANCES IN THE FIELD, SCHOLARS IN MUSLIM CIVILIZATION WERE **CREATING NEW MATHEMATICAL KNOWLEDGE** AND BROADENING THE SCOPE OF **MATH.**

2

NEXT TIME YOU DO YOUR **ALGEBRA HOMEWORK,** YOU HAVE MUSLIM MATHEMATICIAN AL-KHWARIZMI TO THANK. THE "FATHER OF ALGEBRA" INTRODUCED NEW CONCEPTS IN MATH IN BAGHDAD AROUND 830.

3

MATHEMATICAL INVENTIONS FROM MUSLIM CIVILIZATION INCLUDE **THE CREATION OF ALGEBRA,** ADDITIONS TO GEOMETRY, THE DECIMAL NUMBERING SYSTEM, THE SINE AND COSINE, AND MANY OTHERS OF **LASTING INFLUENCE.**

4

AL-KHWARIZMI IS KNOWN IN **LATIN** AS ***ALGORITMI,*** THE SOURCE OF THE MATH AND COMPUTER TERM **"ALGORITHM."**

5

ALGEBRA REVOLUTIONIZED THE WAY PEOPLE LOOKED AT **NUMBERS** AND BROKE AWAY FROM GEOMETRY, WHICH WAS THE ROOT OF THE GREEK CONCEPT OF MATH.

25 NIFTY

6

AL-KHWARIZMI'S book, *Al-Jabr wa-'l-Muqabala,* introduced the basics of the algebra we study today.

7

AL-KARAJI, another mathematician, **BUILT ON THE RULES OF ALGEBRA** and started an algebra school that **THRIVED FOR SEVERAL** hundred years.

8

GEOMETRY WAS USED IN MANY DESIGNS IN THE MUSLIM WORLD, LIKE THE DAZZLING TILE MOSAICS ON MOSQUES AND PALACES. THE MATHEMATICAL SIGNIFICANCE OF MUSLIM TILES AND DESIGNS WAS DISCOVERED ONLY RECENTLY.

9

MUSLIMS WERE THE FIRST TO GIVE **ZERO** A MATHEMATICAL PROPERTY. Without this contribution, there would be no way to tell the difference between numbers like 23 and 203.

10

EVEN POETS LOVED MATH IN MUSLIM CIVILIZATION. THE POET WE KNOW TODAY AS UMAR AL-KHAYYAM CONTRIBUTED TO ALGEBRA WITH HIS IDEAS ABOUT SOLVING COMPLEX EQUATIONS.

11

ALGEBRA MADE ITS WAY TO EUROPE BY THE **12TH** CENTURY.

12

THE NUMBERS WE USE TODAY **(0, 1, 2,...9)** COME FROM THE ARABIC SYMBOLS USED MORE THAN **1,000** YEARS AGO.

13

MUSLIMS HAD TWO COUNTING, OR NUMERICAL, SYSTEMS: ONE in which numbers were written as letters of the alphabet; AND ANOTHER in which numbers were written using ancient Babylonian symbols.

14

THE TWO TRADITIONAL MUSLIM COUNTING SYSTEMS WERE EVENTUALLY REPLACED BY NEW NUMBERS KNOWN AS **ARABIC NUMERALS,** DEVELOPED FROM AN ANCIENT INDIAN SYSTEM.

NUMBER FACTS

15

ARABIC NUMERALS WERE ALSO KNOWN AS *GHUBARI* NUMBERS BECAUSE MUSLIMS INITIALLY USED DUST (*GHUBAR*) BOARDS TO MAKE CALCULATIONS.

16

ARABIC NUMERALS MADE CALCULATIONS MUCH EASIER THAN THE ROMAN SYSTEM, WHICH USED LETTERS LIKE **X, V, I, L, C, AND M** FOR NUMBERS, OR OTHER SYSTEMS BASED ON DOTS, PICTOGRAPHS, OR FINGER COUNTING.

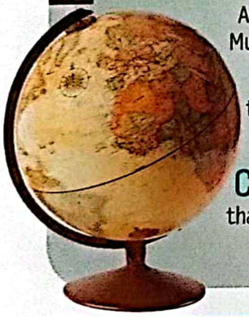
17

Arabic numerals also led to the introduction of **SIMPLE FRACTIONS** and decimal fractions (a fraction in which the bottom number is a power of ten).

18

BEGINNING IN THE 11TH CENTURY, **STUDENTS** STUDYING IN MUSLIM LEARNING CENTERS IN NORTH AFRICA AND SOUTHERN EUROPE INTRODUCED ARABIC NUMERALS TO THE REST OF **EUROPE**.

19



Al-Biruni, one of the greatest Muslim scholars, used **TRIGONOMETRY** to come up with a figure for the **EARTH'S CIRCUMFERENCE** that is very close to the accepted value today.

20

IN THE EARLY **9TH CENTURY** AL-KHWARIZMI CONSTRUCTED TABLES THAT COULD HELP CALCULATE MISSING VALUES IN **ASTRONOMICAL TABLES** THAT DEFINE THE LOCATIONS OF **STARS.**

21

TODAY TRIGONOMETRY IS USED TO **CALCULATE** DISTANCES TO THE STARS, MEASURE THE HEIGHTS OF BUILDINGS AND TREES, AND MUCH MORE.

22

THE SCHOLARS AT THE **HOUSE OF WISDOM** IN BAGHDAD AND AT UNIVERSITIES IN CAIRO, EGYPT, PICKED UP WHERE THE GREEKS LEFT OFF, THEN ADDED THEIR OWN CONTRIBUTIONS TO **GEOMETRY.**

23

WITH A BETTER UNDERSTANDING FOR MATH, PEOPLE WERE ABLE TO USE IT AS A PRACTICAL TOOL IN BUSINESS AND EVERYDAY LIFE.

24

IN THE 10TH CENTURY, IBN AL-HAYTHAM WAS THE FIRST MATHEMATICIAN TO FIGURE OUT HOW TO FIND ALL **EVEN PERFECT NUMBERS**—A SET OF UNIQUE NUMBERS THAT HAS FASCINATED THINKERS SINCE ANCIENT TIMES.

25

COMPLEX **GEOMETRIC PATTERNS** WERE USED IN MUSLIM ARCHITECTURE TO COVER WALLS, CEILINGS, FLOORS, AND ARCHES.

50 Healing Facts About MEDICINE

33
Al-Kindi, a 9th-century scholar, was the first doctor to systematically determine **the dosage** for some drugs.

34
Tribes in the Middle East and Africa were among the ancient peoples who knew of a life-saving process called **inoculation.**

35
In inoculation, or immunization, patients are given a controlled dose of a **disease-causing organism** so that their immune system learns to fight off the disease.

36
Edward Jenner is credited as the pioneer of **vaccination.** Unlike inoculation, Jenner used cowpox rather than smallpox itself to provide protection.

37
The word "vaccination" is derived from the Latin word ***vacca,* meaning "cow."**

38
In 1796 Jenner infected a young boy with cowpox, believing that it would immunize him against the **smallpox** virus. Lucky for all, the process worked.

39
Pharmacies existed in Iraq more than **a thousand years ago.**

40
Smallpox was one of the **deadliest diseases** in the world until 1980, when it was wiped out as the result of a worldwide vaccination campaign.

41
It is estimated that more than **300 million** deaths worldwide in the 20th century can be attributed to smallpox.

42
In 1967 the Turkish Postal Authority issued a stamp commemorating the **250th anniversary** of the first smallpox vaccination.

43
In 1721 Lady Mary Montagu, wife of the English ambassador to **Istanbul,** brought the idea of inoculation to England from Turkey, where it was well-known.

44
Spanish doctor Al-Zahrawi wrote the first **illustrated** book on medicine and surgery.

45
Ibn Sina's *Canon* had 142 **herbal remedies** made from plants, trees, seeds, and spices.

46
Al-Zahrawi had his patients swallow drugs in parcels made of **catgut**—the forerunner to present-day capsules.

47
Thanks to translations from Arabic to Latin by **Constantine the African,** a Tunisian scholar, medicine from the Muslim world found its way to Europe.

48
The largest encyclopedia of **drug usage** still in existence—*Dictionary of Simple Remedies and Food*—was written by the Spanish Muslim Ibn al-Baytar in the **13th century.**

49
Ibn al-Baytar had a system of **classifying plants** centuries before Swedish scientist Carl Linnaeus set up his.

50
Ahmad Ibn Tulun Hospital in Egypt was the first to include a **mental health** department.

Al-Qayrawan hospital in Tunisia

75 ROCKIN' FACTS ABOUT

From geography to gemstones, :holars developed exciting new deas about the natural sciences uring Muslim civilization.

Many areas of science, includ- ng geology, meteorology, botany, nd zoology, are linked to ideas rom a thousand years ago.

Scientists in Muslim civilization sed observation and experimenta- ion to explore and explain such atural phenomena as earthquakes nd the formation of mountains.

The boundaries of the Muslim orld gave scholars a wide range f geographical regions to study.

5 INFORMATION ABOUT MINERALS, PLANTS, AND ANIMALS WAS GATHERED FROM AS FAR AWAY AS THE MALAY ISLANDS.

6 Al-Hamdani, a 10th-century scholar, wrote three books about ways to look for gold, silver, and other minerals in Arabia.

7 The 11th-century scholar Ibn Sina's *The Book of Cure* presented his observations and theories about how the Earth works.

8 The Latin translation of Ibn Sina's book influenced the study of earth science in Europe for more than 300 years.

9 Al-Biruni, another 11th-century Muslim scholar, took the lead in studies about minerals.

10 Al-Biruni's works included a focus on diamonds, rubies, sapphires, and other gemstones.

11 Like other scientists in the medieval Muslim world, Al-Biruni built upon the work of scholars in earlier civilizations.

12 Al-Biruni classified gemstones by color, shape, and hardness.

13 "Hardness" is the ability of a mineral to scratch the surface of softer minerals.

14 Al-Biruni used crystal shape to help him decide whether a gemstone was a quartz or a diamond.

15 Today scientists and jewelers use similar techniques to identify gemstones.

16 Carnelian, a reddish brown gemstone, is prized by Muslims because the Prophet Muhammad is said to have worn a ring with this stone.

17 Carnelians are often engraved with verses from the Quran.

18 Al-Biruni studied India's Ganges River basin and accounts of other geologic formations from the Baltic Sea to Mozambique.

19 Al-Biruni could speak Greek, Sanskrit, and Syriac and wrote all of his books in Arabic and Persian.

20 BY FINDING FOSSILS OF OCEAN LIFE IN ROCKS HIGH ABOVE SEA LEVEL, AL-BIRUNI PROVED THE OCEAN HAD ONCE COVERED PARTS OF INDIA.

21 Al-Biruni's work became a key reference on precious stones.

22 By observing the moon's effects on the ocean, Al-Biruni figured out that tides changed based on the phases of the moon.

23 Al-Biruni discussed the possibility of the Earth being in motion without rejecting it.

24 Like other scholars of the time he believed the Earth was a sphere and discussed the possibility that it rotates on its axis.

25 Six hundred years later the Italian astronomer Galileo Galilei proved Al-Biruni was correct.

26 Al-Biruni also measured latitudes and longitudes and came up with the concept of antipodes, places that are directly opposite each other on the Earth's surface.

27 ONE OF THE EARLIEST EXPLANATIONS OF WHY THE SKY IS BLUE WAS WRITTEN IN THE 9TH CENTURY BY AL-KINDI.

28 Al-Kindi reasoned that the color midway between darkness and light was blue.

29 Al-Kindi was partly right. The sky is not really blue—that's just the way light acts on the atmosphere.

30 Since ancient times some people have believed that stars and planets had souls and minds.

31 Ibn Hazm, a 10th-century scholar from Córdoba, dared to say that "stars are celestial bodies with no mind or soul."

32 Ibn al-Haytham, another earth science innovator, searched for ways to control flooding along the Nile River. A thousand years later his idea became a reality when the powerful Aswan Dam was completed in present-day Egypt.

33 IBN AL-HAYTHAM'S EXPERIMENTS WITH RAYS OF LIGHT LED TO A DETAILED THEORY OF VISION.

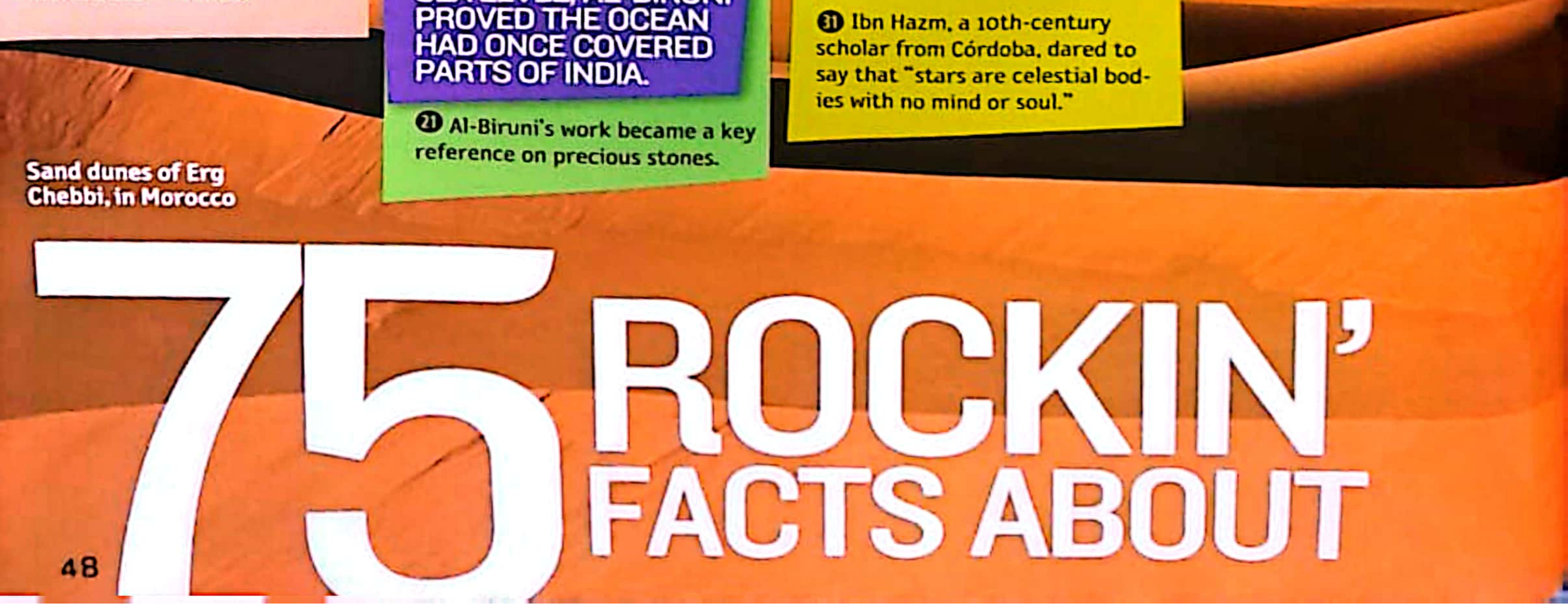
34 His observations paved the way for others to figure out that rainbows are caused by a refraction of sunlight in raindrops.

35 Why does the moon seem to grow in size when it is low in the sky? Ibn al-Haytham said it was a visual trick played by the brain.

36 Later a scholar named Kamal al-Din al-Farisi experimented with glass jars full of water to find out how rainbows are made.

37 Scholars also studied the shape of the Earth, the amount of water versus land, and how rivers, seas, winds, and sea storms formed.

38 Like the ancient Greeks, geographers in Muslim civilization believed the world was round, not flat, and made detailed measurements of the globe.



Sand dunes of Erg Chebbi, in Morocco

39 Scientists now know that the Earth is slightly pear-shaped.

40 Beginning in the 9th century, people in Muslim civilization made very accurate measurements of the Earth, building on the ancient Greek astronomer Ptolemy's findings.

41 NINTH-CENTURY CALIPH AL-MA'MUN HIRED A GROUP OF MUSLIM ASTRONOMERS TO MEASURE THE DISTANCE AROUND THE EARTH.

42 They measured the distance around the Earth to be 25,012 miles (40,253 km). The current measurement is 24,897 miles (40,068 km) at the Equator.

43 Two centuries later Al-Biruni used an equation to calculate the Earth's circumference that "didn't require walking in deserts."

44 In the early 9th century, mathematician, scientist, and astronomer Al-Battani improved existing values for the length of the year and of the seasons that are very close to today's.

45 Observing the seasons led Muslim scholars to study and calculate the tilt of the Earth on its axis.

46 In the late 10th century, mathematician and astronomer Al-Khujandi built a huge observatory to observe the sun.

47 Al-Khujandi calculated the tilt of the Earth's axis relative to the sun and made a list of latitudes and longitudes of major cities.

48 MUSLIM SCIENTISTS STUDIED WEATHER PATTERNS ON LAND AND AT SEA AND WROTE BOOKS ON METEOROLOGY THAT WERE MUST-READS FOR SAILORS.

49 Ahmed ibn Majid, a great Muslim navigator, learned about currents and the monsoons that helped carry vessels to India.

50 Ninth-century Muslim inventor 'Abbas ibn Firnas invented a weather simulation room in which hidden mechanisms created thunder and lightning.

51 Farmers in Muslim lands followed the *Calendar of Córdoba*, an almanac of weather, planting, and harvesting times.

52 MUSLIM SCHOLARS ALSO EXPANDED THE STUDY OF ANIMALS, CALLED ZOOLOGY, DURING THE 9TH AND 10TH CENTURIES.

53 The most famous Muslim writer on animals was the Iraqi Al-Jahiz, who recognized the influence of environment on animals.

54 Al-Jahiz sometimes rented the contents of entire bookshops so he could read all of the books.

55 Though he wrote poetry and fiction, he mixed in scientific observations about things like camouflage and mimicry.

56 Al-Jahiz also investigated animal behavior and communication, especially among insects.

57 Al-Asmai, an Iraqi scholar, was likely the first Muslim scientist to contribute to zoology, botany, and animal husbandry.

58 Al-Asmai's expertise was in breeding horses and camels.

59 Merino wool, most likely from Morocco, resulted from centuries of careful sheep breeding.

60 Today Merino wool is popular among cyclists, hikers, runners, and other outdoor lovers.

61 The concept of pedigree—tracing the ancestry of an animal, especially the horse—originated in Muslim Spain and is used throughout the world today for all kinds of animals.

62 Arabians, which were originally bred as war horses and for their endurance in the desert, are now one of the world's most popular breeds of riding horses.

63 THE MUSLIM WORLD ALSO MADE SIGNIFICANT ADVANCES IN BIOLOGY, ESPECIALLY IN BOTANY—THE STUDY OF PLANTS.

64 A thousand years ago gardens in Muslim civilization were like scientific field laboratories tended by scholars who took detailed notes about the plants they grew.

65 Migrants to the Muslim world, homesick for their native lands, brought fruit trees, like date and pomegranate, then learned how to grow them in the new climate.

66 Some of the greatest botanists of medieval times came from Muslim civilization.

67 Ibn Bassal, a botanist in Toledo, Spain, came up with a way of classifying ten types of soil and explained which ones were best for raising which crops.

68 Al-Ghafiqi, a physician and botanist from Córdoba, Spain, made herbal medicines from plants he collected in Spain and Africa.

69 Ibn al-Baytar, another botanist of the Muslim world, collected plants and herbs from Spain to Syria.

70 He wrote a book outlining the medical uses for 3,000 plants.

71 Ibn Al-Awwam, a 12th-century scholar from Seville, in Muslim Spain, described in great detail how to grow 585 plants and 50 fruit trees.

72 His book also listed ways to fertilize plants and keep them safe from diseases.

73 The knowledge of plants that botanists in Muslim civilization collected and developed led to the cultivation of many useful, beautiful, and nutritious plants.

74 These plants improved the lives of people in other parts of the world, and they enriched gardens throughout Europe.

75 When Europeans colonized the New World, they brought with them many of the plants discovered, studied, and grown in the Muslim world.

EARTH SCIENCE

1
Pharmacies, hospitals, and medical schools were **common** in the early Muslim world.

2
Unlike healing centers in ancient Greece, the **pioneering** health-care system in Muslim civilization focused on diagnosis and treatment rather than on **miraculous cures.**

3
Hospital patients in the early Muslim world might take **syrups,** pills, and powders; undergo surgery; or have a **cast** put on a broken leg.

4
Muslim rulers competed with each other to create the best hospitals that were **open to all.**

5
The **first** major **hospital** was **built** in Cairo, Egypt, between 872 and 874. It was named for Ahmad ibn Tulun, a Muslim ruler in Egypt.

6
Unlike in the Western world today, **herbal medicine** in the 10th-century Muslim world was not seen as alternative medicine.

7
A thousand years ago in the Muslim world medical care was **free** for everyone and included very advanced treatments—even **music therapy.**

8
Because Muslims are **honor-bound** by the Quran to care for the sick, early hospitals treated people of **all faiths,** rich or poor, man or woman.

9
The earliest hospitals in Muslim civilization began in **Baghdad** in the 8th century.

10
Patients with **leprosy** could get treatment at Al-Qayrawan hospital in 9th-century Tunisia, even though many people thought the disease was a **sign of evil.**

11
Al-Nuri Hospital in Damascus, Syria, had inspectors who made sure the care met the **highest standards.**

12
Damascus's highly advanced hospital was one of the first **teaching hospitals** in the world.

13
Doctors in Muslim civilization were required to have **rigorous medical training** in a teaching hospital, much like doctors are today.

14
Muslim hospitals were built in southern Spain and other areas of Europe that were part of **Muslim civilization.**

15
Muslim hospitals were funded by **charitable gifts** called *awqaf.*

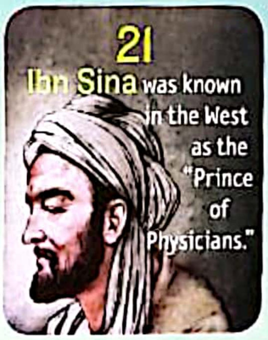
16
Muslim scientist Sinan ibn Thabit ibn Qurra started **mobile** hospital services for rural areas.

17
In the 13th century Ibn al-Nafis accurately described how in the **lungs,** blood coming from the heart **mixes with the air.**

18
Ibn al-Nafis was **not credited** with this great discovery until **1957!**

19
In the 17th century an English doctor named William Harvey discovered the complete blood **circulatory** system.

20
Eleventh-century doctor and philosopher Ibn Sina developed a method for treating **fractured bones** that is still used today.

21


Ibn Sina was known in the West as the "Prince of Physicians."

22


Ibn Sina wrote a highly **influential** medical textbook: the *Code of Laws in Medicine,* or *the Canon.*

23
The *Canon* was printed in Rome in 1593 and went on to become a **standard text** in European medical schools.

24


The *Canon* influenced the layout of modern medical textbooks, such as ***Gray's Anatomy,*** first published in 1858 and now the leading Western medical encyclopedia.

25
Medical books written in the 11th-century Muslim world were **translated** from Arabic into Latin to help spread the knowledge in Europe.

26
The first book solely on **pediatrics,** or children's medicine, was written by Tunisian-born Ibn al-Jazzar al-Qayrawani back in the 9th century.

27
The first known alphabetical classification of medical terms was called *Kitab al-Ma'a,* or *The Book of Water.* The odd title comes from the fact that *Al-Ma'a,* which means "the water," is the first entry.

28
The Book of Water was rediscovered by the modern world, and in 1996 it was published by the government of Oman.

29
Medical books from the Muslim world a thousand years ago show that physicians back then were very skilled at treating **eye diseases.**

30
The *Notebook of the Oculist,* written in the 10th century, describes **130 eye diseases.**

31
As early as the year 1000, physicians in the Muslim world were working to find ways to **prevent blindness.**

32
Of the 30 ophthalmology textbooks written during early Muslim civilization, **14 still exist.**

1 The study of astronomy in the Muslim world included scholars from many countries and cultures.

2 Keeping a close watch on the sky helped Muslims find the direction of Mecca.

3 The Quran encourages the exploration of the universe.

4 Muslim civilization was the first to use observatories and large instruments to study the heavens.

5 WORKING IN TEAMS LET ASTRONOMERS STUDY PLANETS AND STARS IN MORE DETAIL THAN EVER BEFORE.

6 The Toledan Tables are astronomical charts that predict the movements of the moon, sun, and planets and take their name from Toledo, a city in Muslim Spain.

7 The tables were written in the 9th century by Al-Zarqali, known in Europe as Arzachel.

8 For 300 years Muslim-ruled Toledo was the world's center for astronomy and science.

9 Caliph Al-Ma'mum set up a government-funded observatory in Baghdad so astronomers could work together in one place.

10 Scientists at Al-Ma'mum's observatory discovered that the solar apogee, the point at which the sun is farthest from the Earth, changes over time.

11 We now know the solar apogee changes because the whole solar system moves within our galaxy.

12 The Maragha Observatory, built in northern Persia (now Iran) in 1263, had a library with more than 40,000 books.

13 The astronomer Jamal al-Din introduced instruments from the observatory to China in 1267.

14 The foundations of the Maragha Observatory still stand in Iran.

15 The 15th-century astronomer-mathematician Ulugh Beg created an observatory in Samarkand (now in Uzbekistan) while he was Sultan.

16 Ulugh Beg calculated the length of a year at 365 days, 6 hours, 10 minutes, and 8 seconds—just 62 seconds longer than the figure used today!

17 In the 9th century 'Abbas ibn Firnas built a glass planetarium in his house that showed images of stars and planets.

18 HIS PLANETARIUM EVEN FEATURED ARTIFICIAL THUNDER AND LIGHTNING.

19 Many astronomical instruments created in the early Muslim world greatly influenced the development of modern astronomy.

20 These new kinds of astrolabes, sextants, and quadrants measured the height of stars more accurately than ever before.

21 SEXTANTS WERE THE GPS OF THE MEDIEVAL WORLD.

22 Astrolabes, sextants, and quadrants helped make possible the European age of exploration.

23 An amazing observatory built by Taqi al-Din in Istanbul, Turkey, had an impressive array of extremely large instruments.

24 Large instruments made more accurate measurements possible.

25 THE OBSERVATORY IN DAMASCUS, SYRIA, HAD A 20-FOOT (6-M) QUADRANT AND A 56-FOOT (17-M) SEXTANT.

26 Today some of the largest optical telescopes are in the Canary Islands.

27 The need to know prayer times and the direction of Mecca led to substantial improvements in the astrolabe, an ancient instrument.

28 An astrolabe shows how the 3-D sky would look if it were flat.

29 People used astrolabes to tell time day or night, navigate on land, and calculate sunrise and sunset.

30 Astrolabes are sometimes called the pocket watches of the medieval world.

31 Observations made with astrolabes helped lead to the birth of modern astronomy.

32 The astrolabe is considered the most important astronomical observational device before the invention of the telescope.

33 It could take up to six months to build an astrolabe because the makers had to do extensive calculations, engrave all the parts, and then assemble them all by hand.

34 THE OLDEST KNOWN ASTROLABE MADE IN THE MUSLIM WORLD IS FROM 10TH-CENTURY BAGHDAD.

35 Using a huge astrolabe, astronomer Ibn Yunus recorded more than 10,000 observations of the sun's position during a 30-year period.

36 The astrolabe was based on the ancient Greek model of the universe described by Ptolemy that showed the Earth at the center.

37 In 1387 Geoffrey Chaucer, author of *The Canterbury Tales*, gave his young son an astrolabe made to work for Oxford, England.

Ahmad al-Mizzi's quadrant; foreground: armillary sphere

75 OUT OF THIS WORLD FACTS ABOUT

38 The universal astrolabe, developed in Toledo, Spain, in the 11th century by Al-Zarqali, changed star mapping forever.

39 The universal astrolabe could be used at any location.

40 Jabir ibn Aflah, who lived in the 1100s, designed the first portable celestial globe to measure coordinates of planets and stars.

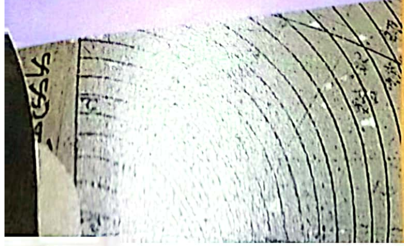
41 Since ancient times astronomers have used 3-D models of the heavens called armillary spheres.

42 These spheres have rings set at different angles to show the paths of planets and stars.

43 By the 10th century the Muslim world was producing two kinds of complex armillary spheres: demonstrational and observational.

44 DEMONSTRATIONAL ARMILLARY SPHERES PUT THE EARTH AT THE CENTER WITH THE SUN, TROPICS, EQUATOR, AND POLAR CIRCLES MOVING AROUND IT.

45 Observational armillary spheres had sighting devices on the rings but did not have the Earth at the center.



46 Using armillary spheres, astronomers produced flat charts of the heavens, which were then used to make astrolabes.

47 *THE ALMAGEST*, BY 2ND-CENTURY B.C.E. GREEK SCHOLAR PTOLEMY, HAD AN IMPORTANT INFLUENCE ON ASTRONOMERS OF THE MUSLIM WORLD.

48 Ninth-century astronomer Al-Farghani, inspired by Ptolemy's work, wrote several important books on astronomy.

49 The medieval Italian poet Dante probably gained his astronomical knowledge by studying the writings of Al-Farghani in Latin.

50 One of Al-Farghani's most important inventions was the Nilometer. Created in 861, it measured the water level of the Nile at Cairo and predicted when the river would flood each year.

51 Scientist Al-Battani combined elements of the celestial globe and the armillary sphere to create a new instrument called *al-baydha*, meaning "the egg."

52 The creation of the egg allowed astronomers to assign stars exact coordinates.

53 Al-Battani is also credited with timing new moons, calculating the length of solar years, and predicting eclipses.

54 Star maps created in the Muslim world were used in Europe and the Far East for centuries.

56 THE ASTRONOMER 'ABD AL-RAHMAN AL-SUFI WAS THE FIRST TO MENTION A STAR SYSTEM BEYOND OUR MILKY WAY GALAXY.

57 In 964 Al-Sufi named his find "little cloud." Today we call it the Andromeda galaxy.

58 The Andromeda galaxy is about 2.6 million light-years from Earth.

59 Our Milky Way galaxy contains between 200 and 400 billion stars.

60 The Milky Way is about 1,000 light-years thick, 100,000 light-years wide, and 300,000 light-years around.

61 The terms "zenith" and "azimuth" are of Arabic origin.

62 The astronomer Qutb al-Din al-Shirazi and his student Kamal al-Din al-Farisi explained that rainbows are caused by the refraction of the sun's rays in raindrops.

63 According to Copernicus, Ibn Rushd, a philosopher and astronomer, may have observed sunspots.

64 The 17th-century astronomer Galileo Galilei built on Latin translations of works written by astronomers of the Muslim world.

65 Six hundred years before Galileo, Muslim astronomer Al-Biruni explored the idea that the Earth rotated on its own axis.

66 Al-Biruni is sometimes referred to as the Leonardo da Vinci of his day.

67 Astronomer-scientist Thabit ibn Qurra lived in Baghdad, where he revised many Arabic versions of ancient Greek and Syriac science texts before his death in 901.

68 IT WAS EASIER FOR EARLY CIVILIZATIONS TO OBSERVE PLANETS AND STARS WITH THE NAKED EYE BECAUSE THERE WERE NO BRIGHT CITY LIGHTS.

69 Human eyes can take up to an hour to adjust to the night sky. This "night vision" makes it easier to see things that are farther away and less bright in the sky.

70 There are five planets that can be easily seen with the naked eye: Mercury, Venus, Jupiter, Mars, and Saturn.

71 Unlike some earlier thinkers, the scholars of Muslim civilization did not believe that the stars and planets were living beings.

72 The Quran talks about orbits and other astronomical phenomena.

73 The groundbreaking observations and discoveries made by astronomers during Muslim civilization had a huge impact on astronomy in the Western world.

74 Among those influenced by these medieval astronomers was Nicolaus Copernicus, a Renaissance scholar from Poland who is often considered the founder of modern astronomy.

75 Copernicus relied heavily on work done by Al-Battani, Ibn al-Shatir, Nasir al-Din al-Tusi, and