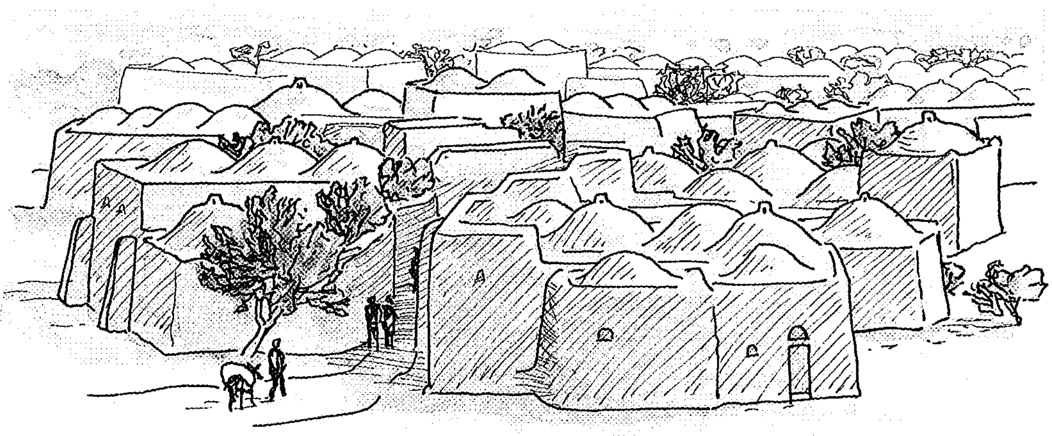
Traditional architecture in the Middle East has ways of...

KEEPING COOL

WRITTEN BY WARREN JOHNSON ILLUSTRATED BY AARON JOHNSON



MUD-DOMED HOUSES, AFGHANISTAN

For centuries, the older parts of many Middle Eastern cities have been known for their narrow, busy streets, for their covered bazaars, and for the quiet, stony sanctuary of their mosques. Because visitors often find these aspects of the urban environment so fascinating, it is easy to overlook the ways in which they constitute skillful and scientific adaptations to the harsh demands of a hot, dry climate.

Of course, not all Middle Eastern cities are located in such climates. Seacoast cities such as Jiddah and Kuwait are humid as well as hot, while winters in the mountains of Turkey, Iran and Yemen can be very cold. The architectural adaptations to those climates are different, but from Morocco in North Africa to Pakistan on the edge of the Indian subcontinent there are vast stretches of hot, dry desert and semidesert. In those regions, in cities like Tehran, Shiraz, Isfahan, Aleppo, Jerusalem, Amman, Riyadh, Madinah, Makkah and San'a—and in many more towns and villages—people have learned how to build so as to keep cool during the day and warm at night.

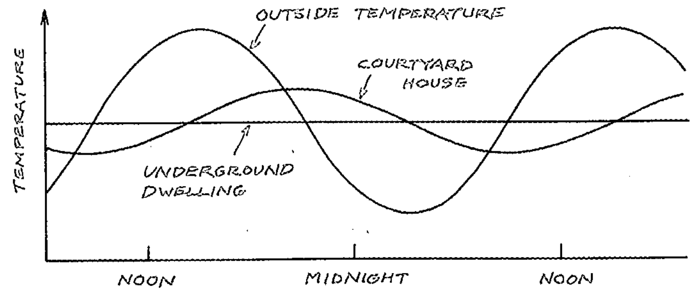
Thick walls and roofs, for example, temper both the heat of the day and the chill of the night. The narrow streets and alleyways fend off both the sun's glare and the often dusty winds. The traditional building materials of the Middle Eastern city—earth and stone—are available locally in abundance, and they have been used in architecturally pleasing and durable ways.

These desert and semidesert cities are doubly impressive because they have integrated the environmental demands of the desert, and cultural and religious values such as the privacy of the family, into an architecture that meets both physical and social human needs.

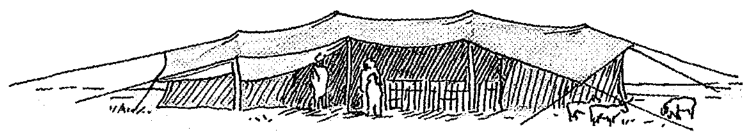
The builders of these cities took advantage of the one key asset offered by the desert climate: temperatures which, though very high during the day, cool significantly at night. This cooling occurs because of the low humidity of desert air: It is the moisture in air that holds heat.

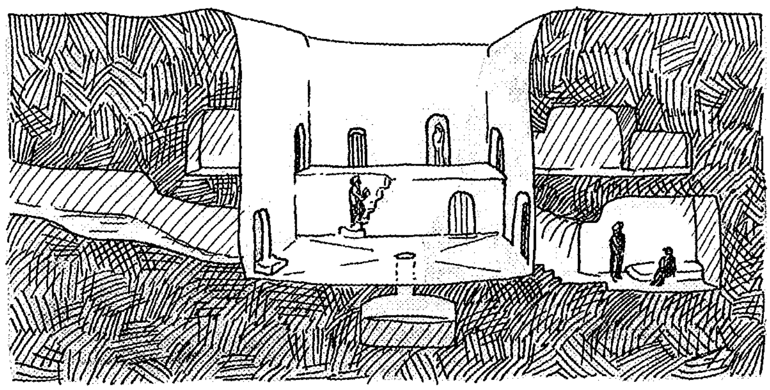
Both the cooling of the night and the heating of the day are driven by the physical process of radiation. It is of course solar radiation—sunlight—that produces the heat during the day. At night, heat radiates from the warmed earth back into space. By dawn, the air can be quite chilly, and the buildings will have cooled off a great deal as well.

To take advantage of night cooling in the desert, builders employ what is known as *thermal mass*, that is, they build with heavy, dense materials that can absorb substantial amounts of heat from the sun during the day. Stone and earth have very great thermal mass, and the thick walls and roofs built with them accumulate heat during the day and carry it into the evening, keeping interior spaces warm as outside temperatures drop. By morning, the thermal mass of the buildings has cooled off, and the cool mass keeps the interior spaces cool again during the day as the outside temperature rises.



TEMPERATURE-MODERATING EFFECTS OF THERMAL MASS


MINIMUM THERMAL MASS: BEDOUIN TENT, ARABIAN PENINSULA


MAXIMUM THERMAL MASS: UNDERGROUND HOUSE, TUNISIA

Thermal mass thus not only moderates the extremes of desert temperatures, but also creates a comfortable time lag in the interior temperature changes: The highest temperatures are only reached late in the day and are carried into the evening, well after the highest outdoor reading is past and the day has begun to cool. In the chart, top, above, the temperature extremes are reduced, typically, by two-thirds and the time lag is six hours, but of course both parameters can vary significantly depending on the actual amount of thermal mass in a building.

Nomadic peoples, however, cannot live in dwellings with great thermal mass because they need lightweight, easily transportable materials to protect themselves against the elements. Their solution is simpler: Their densely-woven tents guard against the direct effects of the sun, and provide for cooling through natural ventilation. A tent wall or backstrip, pinned in place, can be easily moved to catch or block winds as needed or, at night, to enclose the tent completely.

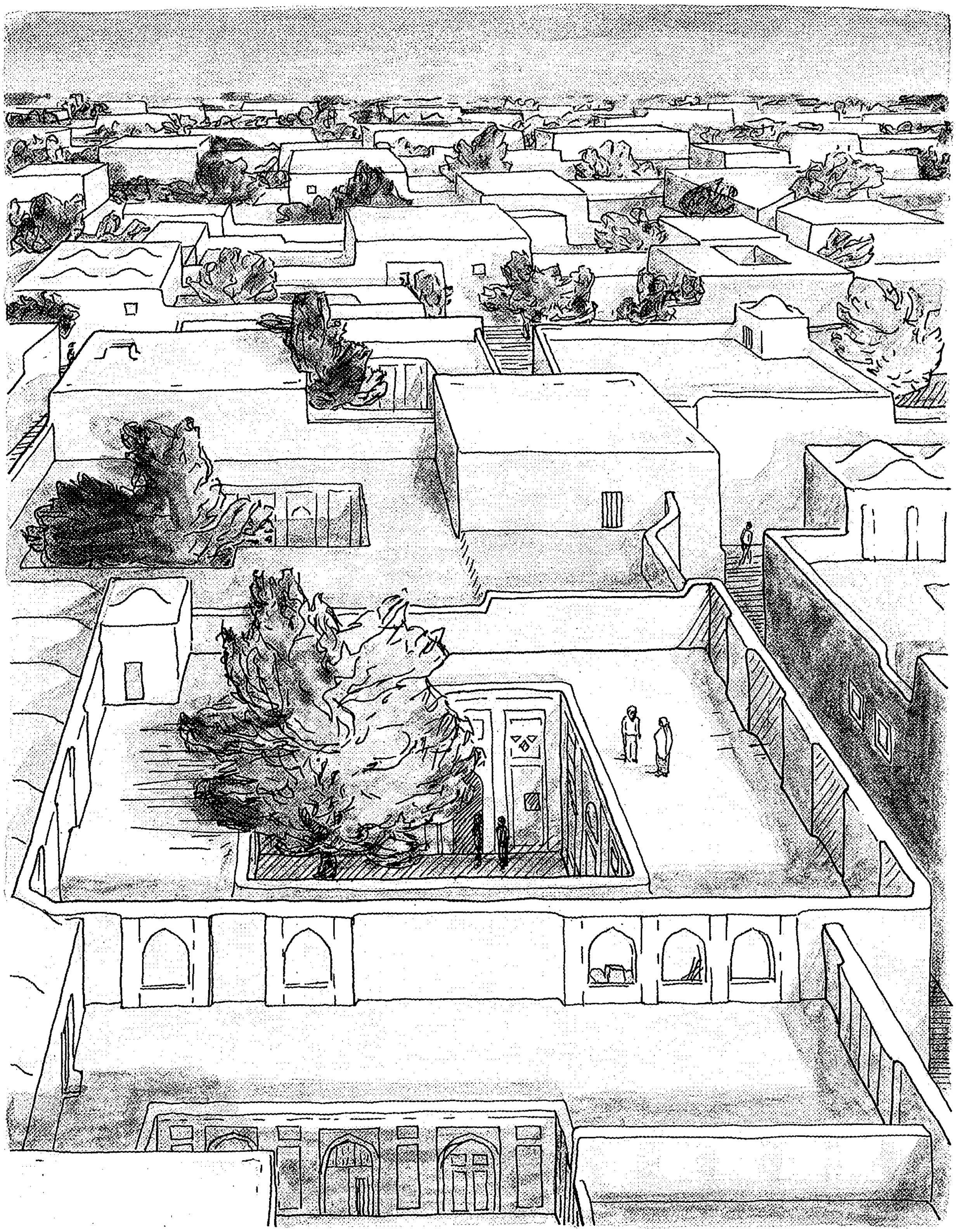
At the other extreme are underground dwellings, such as those at Matmata in Tunisia, where the surrounding earth provides virtually infinite thermal mass. This keeps the temperature almost uniform day and night, as in a cave.

In terms of thermal mass, however, the most common type of dwelling in the desert is a compromise between the tent and the cave: It is the courtyard house, and it provides so many advantages that it is also used in warm countries well away from the rigorous climate, including in southern Europe and the Americas.

From an energy-use perspective, the key

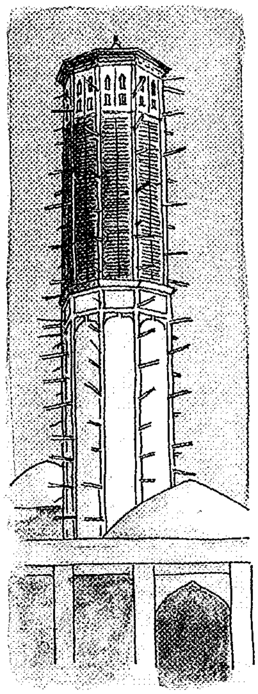
advantage of the courtyard house, with its single row of rooms arranged on three or four sides of the open space, is that it presents a maximum amount of surface area from which to radiate heat at night. The courtyard brings the night air into the heart of the dwelling, so the house, like any well-designed radiator, exposes as much cooling surface to the air as possible.

The courtyard house offers social advantages, too. It provides an open space for household activities while still allowing the privacy which is so important in Muslim



COURTYARD HOUSE, AFGHANISTAN

societies. In more moderate climates, the light and fresh air that the design admits into the interior of the dwelling are important as well. With ample light in the middle of the courtyard house, its exterior walls can be windowless, with the only essential penetration being the entry door. That, in turn, creates what amounts to a private outdoor sitting area for enjoyment in the evenings, and also allows dwellings to be built butting together, with common walls that can significantly reduce building costs. It fosters the higher population densities that contribute to the social vitality of public spaces in Middle Eastern cities.



OMNIDIRECTIONAL WIND TOWER, IRAN

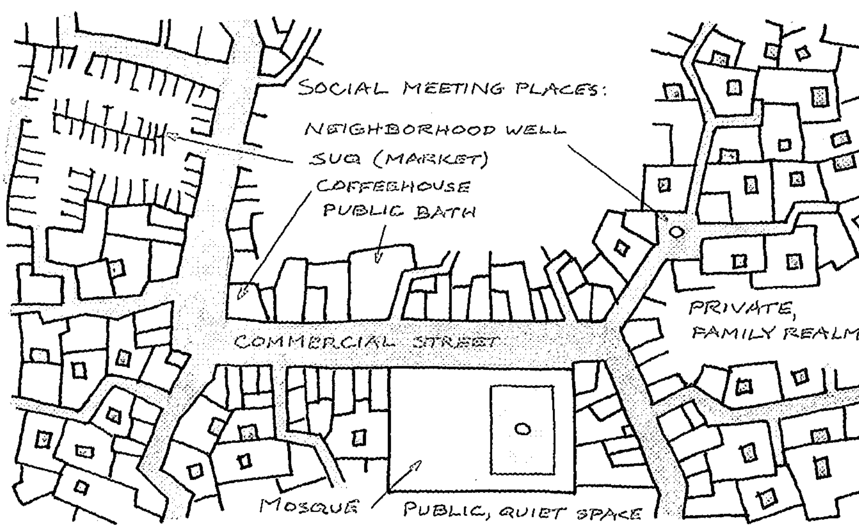
Streets and alleys are kept narrow, which leaves them mostly shaded—an important criterion in Middle Eastern urban design—and contributes further to high population density. Traditionally, main commercial streets were required to be wide enough to permit two loaded camels to pass each other; residential streets only had to be wide enough for one camel. Short, dead-end alleyways are common, too; they are usually owned by the people whose properties they give access to, often members of the same extended family. These twisting, narrow streets and alleyways effectively break up the flow of wind through the city.

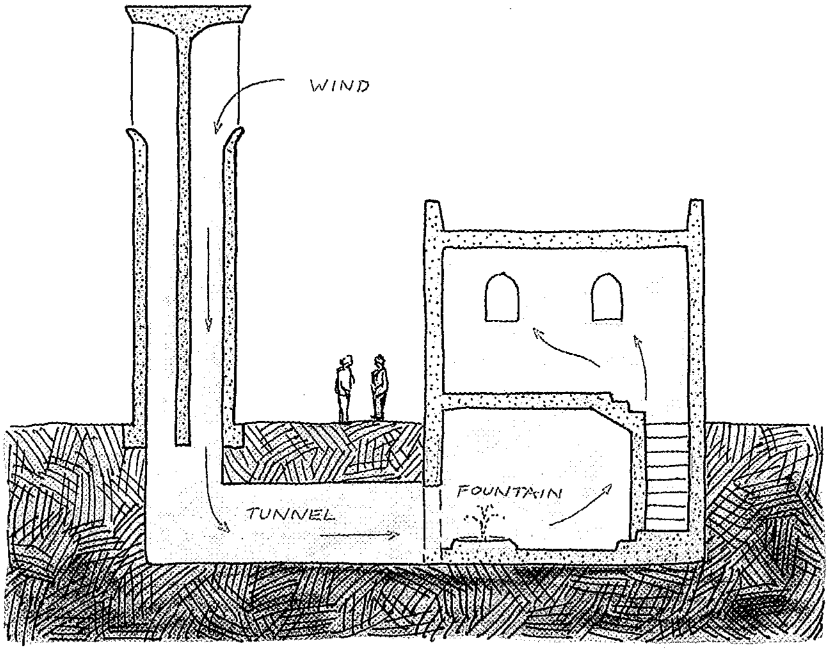
The necessity of preserving social harmony in such close quarters is reflected in the Hadith, the sayings of the Prophet Muhammad. "To God," he is recorded as saying, "the best friends are those who are good to each other, and the best neighbors are those who are good to each other." The privacy of the family is always an important value: A hadith says, "If a man pushes aside a curtain and looks inside without permission, he has then reached a point which he is not allowed to reach." Cooperation when building is essential: "You must not build to exclude the breeze from [your neighbor], unless you have his permission." And the obligation of homeowners to share a common wall is also mentioned: "A neighbor should not forbid his neighbor to insert wooden beams in his wall."

Under certain conditions, however, the courtyard house proves to be unsuitable. High mountain elevations can make winters too cold for such an open design; the high humidity near large bodies of water reduces the nighttime cooling that it provides. Strong, dust-laden winds, common in many parts of the Middle East, can cause problems, too. The "120 days' wind" that blows throughout the summer in eastern Iran, for example, brings with it not only dust but at times also salt swept up from salt pans.

Under such circumstances, builders had to eliminate the courtyard and cover the entire dwelling. While this change also eliminates the easy penetration of light and air, it has produced some of the most striking architecture in the Middle East. In the Atlas Mountains of North Africa it has led to what are called "mud- lump" buildings, where thermal mass is employed so extensively as to create nearly cavelike temperature conditions. In some places, entire villages are covered over, resulting in much-moderated temperature fluctuations.

Iran is particularly rich in examples of sophisticated adjustments to harsh environmental challenges, of which wind towers are among the most interesting. If the wind blows consistently from one direction, the wind





How a wind tower works

to evaporate water—80 kilocalories for every gram—and the removal of that much heat from the interior of the dwelling has a strong cooling effect.

In dry air, the chilling effect of evaporation is especially noticeable because the rate of evaporation is high. This is what makes evaporative coolers effective. In humid climates, however, where the air is nearly saturated with water, they work poorly—which is why they are being displaced by air conditioners, which work well in both dry and humid conditions.

Evaporative cooling was also used to keep water in large cisterns cool for use in the summer. Most such cisterns have gone out of use now, mainly because of the difficulty of keeping stored water clean and sanitary. But water is still often stored in unglazed, covered clay jugs like amphorae, where it stays cool because of evaporation through the porous walls of the container. And evaporative cooling survives in the many pleasures that gardens provide in the desert. The moisture that water introduces to the small area of a garden makes it slightly cooler and slightly more humid than the surroundings, and turns it into a welcome respite from the desert's aridity.

tower—called *badgir* in the area of the Arabian Gulf—can face that direction, as shown on page 16, catching the breeze and directing it down into the dwelling. More commonly, however, winds are variable, and in such areas the towers are open in several directions.

Wind towers are often quite tall, which not only helps them catch more of the breeze, but also provides ventilation even when there is no wind. This trick also involves thermal mass, as the sketch above shows. The mass of the stone-built tower itself cools off at night. The following day, as the air is warmed by the sun, the tower remains cool. The air that comes in contact with the tower is cooled and, because cool air is heavier than warm air, it falls down through the tower into the space below. Dwellers in the houses also often hang wet cloths on the horizontal wooden bars that protrude from the wind tower's walls, which has the effect of further cooling the air being drawn into the tower. In the winter, of course, wind towers must be closed off from the rest of the house, or else they will function like chimneys, allowing the warm air in the house to rise up and be lost.

In more elaborate cooling constructions, the cooling air from a wind tower is directed past water in a fountain or a pool, or moved through a damp tunnel, in order to take advantage of the further cooling effects of evaporation. A good deal of heat is required

Markets and bazaars were often completely covered in the Middle East to protect the goods on sale from the almost constant sun, as well as the infrequent rains. Even when completely covered, however, builders found ways both to ventilate them and to keep them from being too dark.

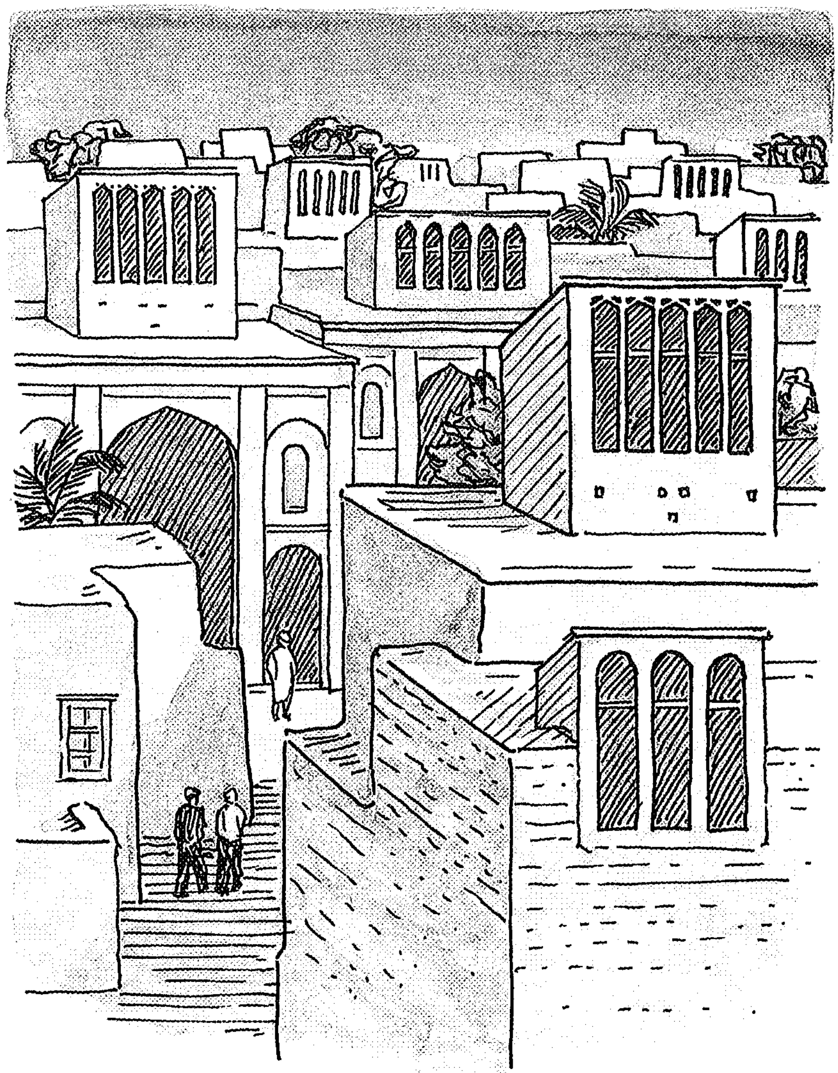
The main passageways of a bazaar are usually covered with barrel-arched roofs or a series of domes. This construction capitalizes on the engineering advantages of arches, but it also has the virtue of allowing the day's heat to rise into the highest parts of the arches; air vents placed there allow the hot air to escape. As air rises out of the vents, fresh air is naturally drawn in from outside—mostly through the bazaar's street-level entrances—to replace it.

The vents, in the form of caps or lanterns atop the domes or the arches, have openings in all directions that allow the air to escape and also

COVERED BAZAAR, IRAN

provide a modest amount of light. (Natural light is now universally supplemented with electric light.) From the outside, the arches force the passing breeze to speed up slightly as it flows up and over them. This acceleration creates suction and draws hot air out more rapidly. To encourage this Bernouilli effect, the barrel arches are often built at right angles to the direction of the prevailing summer winds.

But not all low-rainfall areas are low in



Directional wind towers, Iran

humidity, especially near bodies of water like the Red Sea and the Arabian Gulf. The city of Jiddah illustrates how the wealthy merchants of a port modified their dwellings to make them as comfortable as possible under humid conditions. With limited night-time cooling, continuous ventilation became the most important objective. Families built tall, airy houses of up to seven stories, originally with generous amounts of space between them so as not to interfere with the flow of air.

The availability of imported wood in the city meant that, even though the structures were of stone, their interiors could be built of wood in a light and open plan that promoted the flow of air through the house. The outside breezes were collected in distinctive bay windows cantilevered out from the stone walls. Known as *rawashin*, these windows were covered with decorative wood screens that allowed the occupants to see out but still preserved the privacy of the family (See *Aramco World*, July-August 1993).

Mountainous regions, with their cold winters, have presented builders with a different challenge. In Morocco and Yemen, tall, skyscraper-like structures were built butted together, to insulate each other, but with their south-facing sides exposed to soak up as much sun as possible. Even when temperatures are low, the winter sun in the desert can be intense enough to make it worthwhile to collect it.

In the mountains of the Asir region of Saudi Arabia, between Makkah and Yemen, however, the architectural response has been closer to that of the cold parts of Europe and North America. In such climates, the goal is the opposite of that of the courtyard dwelling: radiating surfaces are kept to a minimum, usually by building compactly. The dwellings of Asir demonstrate this with a squarish plan several stories high, basically similar to the two-story Swedish farmhouse or the homes of colonial New England.

In Europe and North America, however, wood was abundant and cheap, and wood is a good insulator. But it is difficult to come by in the Asir, and in the cold mountain air, the earth and stone, whose thermal mass is so valuable in hot regions, becomes a liability: It loses heat to the outside and, as the winter progresses, occupants of a stone house find themselves surrounded by walls which grow ever colder—and remain cold until the warming of the spring.

All of the principles used by the desert builders are the same ones that underlie efforts in the temperate regions of the world to make solar houses cost-effective. While much early solar-heating technology—with its collectors, heat-storage devices, pumps, sensors, and electronic controls—turned out to be too complex and expensive, its "passive" counterparts have, like the systems of the desert builders, proved successful. Walls of high thermal mass serve both to store heat for cold days and, in effect, "store coolness" for hot ones. Natural heating and ventilation through well-placed windows can also do much to keep a dwelling comfortable.

Modern-day builders in both the West and the Middle East have one key advantage over the traditional desert builders: the availability of glass and insulation. Glass allows much more efficient collection of warmth from the winter sun, while insulation saves the warmth once it is collected. Yet in their scientific principles, the modern passive-solar house is very much in the tradition of the dwellings of the desert. 🌐

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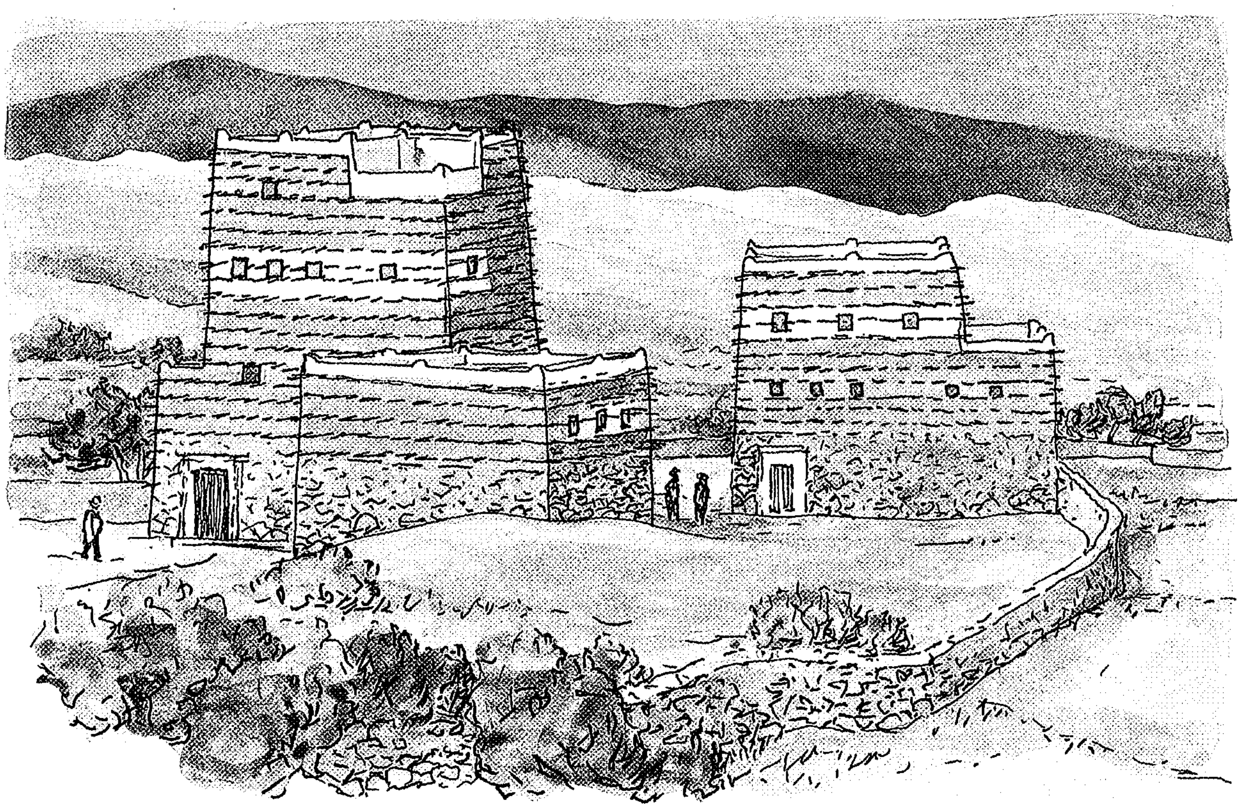

ASIR, SAUDI ARABIA