



Bioclimatic Devices of Nasrid Domestic Buildings

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1. INTRODUCTION

Islamic society absorbed the influence of all the cultural areas wherever it became established. In the Mediterranean Basin there was the influence of the Greco-Roman world using square or rectangular courtyards with arcades on all four sides. On the other hand, in the Middle East, they adapted the Persian Sassanid, Babylonian and Egyptian traditions.

In spite of its nomadic origins,

Islamic civilization quickly developed into a widespread, predominantly urban culture. The community grouping was often constituted as a defense against potential enemies, and particularly against challenging, which tended to be hostile in the areas of expansion of the Islamic World, including the south of the Iberian Peninsula, although such conditions were less harsh in the territories of *al-Andalus*.

The cities had to be compact and their public spaces narrow



Image 1.1. Aerial view of Marrakesh, Morocco (ca. 1993). © Yann Arthus-Bertrand/CORBIS.

to keep out the strong, dry winds of the desert. The narrow alleys kept out the direct sunlight from the buildings, with their close proximity providing additional protection. In addition, the massive constructions with earth, adobe, bricks or stone walls helped to maintain the necessary coolness and humidity during the hottest hours of the day (Image 1.1).

The Tunisian Muslim historian Ibn Khaldūn¹ wrote in 1377 his *Muqaddimah* or the *Prolegomena*, which records an early view of universal history. The *Muqaddimah* anticipated the meteorological climate theory of environmental determinism, later proposed by Montesquieu in the 18th century. Ibn Khaldūn studied “the physical environment in which man lives in order to understand how it influences him in his non-physical characteristics.” He explained the differences between different peoples, whether nomadic

or sedentary, including their customs and institutions, in terms of their “physical environment-habitat, climate, soil, food, and the different ways in which they are forced to satisfy their needs and obtain a living” (Gates, 1967: 415-422).

In his *Muqaddimah* Ibn Khaldūn stresses the task of architecture to control the environment: “The craft of architecture is the first and oldest craft of sedentary civilization. It is the knowledge of how to go about using houses and mansions for cover and shelter. This is because man has the natural disposition to reflect upon the outcome of things. Thus, it is unavoidable that he must reflect upon how to avert the harm arising from heat and cold by using houses which have walls and roofs to intervene between him and those things on all sides.”

Between the 10th and 14th centuries, spanning the late Middle Ages, there was a well-documented warm period in North Atlantic regions, called the *Medieval Warm Period* or *Medieval Climate Optimum*. Therefore, the bioclimatic aspects in the dwellings of *al-*

¹ Ibn Khaldūn lived in Granada during the kingdom of Muhammad V after he had recovered the throne following his exile in Fez. In 1364 he was entrusted with a diplomatic mission to the King of Castile, Pedro the Cruel, to endorse a peace treaty. In Granada, Ibn Khaldūn quickly came into competition with Muhammad's vizier, Ibn al-Khatib. His machinations resulted eventually in Ibn Khaldūn sending him back to North Africa.

Andalus were developed in order to obtain natural refrigeration. To a lesser degree, also specific mechanisms are also noticed in these buildings to protect against the cold, especially in the last *Nasrid* period (14th and 15th centuries) and mainly, in *Morisco* times (16th century), when a colder period known as *Little Ice Age* was developing.

2. CLIMATIC CHANGES IN THE PAST AND THEIR INFLUENCES ON SOCIETIES

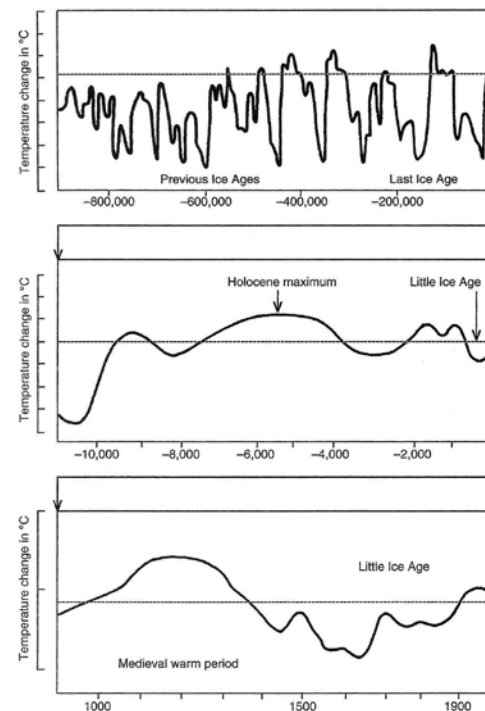
2.1. The Roman Climatic Optimum

The last Iron Age, characterized by wet and cool summers and mild rainy winters, lasted roughly through the whole period of the Roman Kings and the Republic (Image 2.1). The water table was probably higher than it is today, and so North Africa could become the granary of the Roman Empire (Lauer and Bendix, 2004: 287).

Image 2.1. Hypothesis of the climate balance in the first IPCC report (1990). Variations between cold and warm periods in the last 12,000 years. Adapted from: IPCC Report 1990; C. K. Folland *et al.*, "Observed Climate Variations and Change" (in: Houghton, 1990: 195-238).

The climate became warmer at the end of THE 1st century BC. Temperatures were then probably similar to those today (Schönwiese, 1995: 91).

Whereas Carthage, the great power of the southern Mediterranean Sea, reached its high point during the early colder phase, Rome had its golden age after the warming began, when the political center of gravity had shifted to the northern side of the Mediterranean. Rome initially expanded southward and struck out north only after the warming had begun (Behringer, 2007: 61-



62). The fact that passes over the Alps were clear all year round made it easier to conquer and control the transalpine provinces of Gallia, Belgica, Germania, Raetia and Noricum. This great expansion coincided with a quite warm but not excessively dry period, which is known in climate history as the *Roman Climatic Optimum* (Zolitschka *et al.*, 2003: 98). This warming lasted from the 1st century AD until approximately the 5th century. During this age, more people lived on our planet than at any time before. This level would be reached again only a thousand years later, during the warm period of the High Middle Ages.

The ancient climate optimum favored the creation of other empires through the Middle East to East Asia. The Han dynasty (202 BC to AD 220) flourished in China at almost exactly the same time as the Roman Empire.

2.2. The Early Medieval Pessimism

Harsh climatic factors also contributed to the crises in the Roman Empire. The migration of the Germanic people over the territory of Rome began under

the conditions of the climatic optimum, possibly as a result of major demographic growth in the north. The great migration period was triggered in AD 375 when the Huns broke out of the Asian steppes, and precipitated the westward migration of the Germanic tribes (Behringer, 2007: 62-64).

This early medieval cooler period developed from AD 450 to 750, and there are indications that in central England a lasting rise in temperatures, by 1 to 2°C, did not begin until around the year 1000 (Schönwiese, 1995: 81-6 *passim*). The early Middle Ages were a time of extreme insecurity in Europe: the population level fell to a low that was never again reached at any later period.

In northern, western and central Europe as well as in the northern Mediterranean regions, the cold was mainly associated with wetter conditions. On the other hand, in parts of Asia, the Near East and North Africa there persisted a greater aridity, and Rome's traditional granary dried up (Lamb, 1982: 149, 159f). In southern Italy, Greece, Anatolia and Palestine, people moved to the coasts and left the hinterland

largely uninhabited. This was the period when great cities went into decline: Ephesus, Antioch and Palmyra in Asia Minor. Some six hundred settlements were abandoned in Arabia, where elaborate irrigation systems had previously kept agriculture going. Many settlements from this time were later swallowed up by the Syrian and Jordanian desert (Oesterdiekhoff, 1999: 123-32, 126).

The expansion of the Arabs and the associated spread of Islam happened at this time with the occurrence of adverse climatic conditions in their traditional homelands (Lamb, 1982: 160).

2.3. The Medieval Warm Period

The idea of a *Medieval Warm Period* was formulated in 1965 by Hubert Lamb, who based his conclusions on historical texts and physical data regarding the climate. He located its peak between AD 1000 and 1300, in the High Middle Ages (Flohn, 1985: 131). During this time there was a pattern of warm dry summers and mild winters, and the large glaciers retreated in the period between 900 and the second half of the 13th century, not only

in Europe and North America but all around the world (Grove and Switsur, 1994: 143-69).

Lamb's original estimate was of a 2 °C warming (based on proxy data). This became a matter for controversy, because it far exceeded the 0.6 °C measurement for warming in the 20th century. Lamb estimated the warming at 1 to 2 °C above the average in the "normal period" from 1931 to 1960. In the far north it was as much as four degrees warmer (Lamb, 1965: 13-17). Other researchers use instead the concept of a *Medieval Climatic Anomaly* (Bradley et al., 2003: 404-5).

In this period there were wide regional differences between countries north of the Alps and the Mediterranean area. There would be heavier rainfall and a seasonally differentiated evolution of temperatures. The spring was three degrees warmer between 1170 and 1310 than in the climatic period from 1891 to 1960, and the glaciers retreated. After the end of the warm phase there was a cooling that reached a peak in the 1340s. In the Mediterranean a period of great aridity can be detected between 1200 and 1310 (Alexandre, 1987: 775-808), and

at this time the water irrigation system of Granada dating from the 11th-12th centuries had to be improved by the *Nasrid* dynasty.

The high *Medieval Warm Period* also saw harsh climatic extremes, such as the severe winters of 1010-11 (Lamb, 1982: 157) or 1118 (Camuffo, 1987:43-66, 58-64). The 1180s, on the other hand, were the decade with the warmest known winters. There had been warm or hot periods before then, such as the one between 1021 and 1040. The summer of 1130 was so dry that it was possible to wade across the Rhine, and in 1135 the Danube had so little water that people could cross it on foot.

Hot dry summers were the rule from the 1180s in a remarkably long warm phase, until a cold stormy season in 1251. The longest phases of persistent summer heat occurred in Central Europe between 1261 and 1310, and again between 1321 and 1400.

Surprisingly, the spring seasons were quite varied during the warm period of the Middle Ages. Cool or cold temperatures alternated with moderate, warm, or hot, although

not as commonly as in the Little Ice Age. The warm, often dry autumnal weather in the second half of the 13th century features in relatively few reports. Unfavorable harvest periods became more frequent in the early 14th century, at the onset of the *Little Ice Age* (Glaser, 2001: 61-92).

The tree line in the Alps rose to over two thousand meters, a level not attained even in the *Bronze Age Optimum* and far higher than in the 20th century (Lamb, 1982: 157). In Germany, England, southern Scotland and southern Norway vines were cultivated not only in the old Roman areas, but at locations two hundred meters above present-day levels and much further afield (Weber, 1980). Viniculture indicates that night frosts were rare and that there was sufficient sunshine in summer (Lamb, 1982: 170f).

Pollen analysis has shown that Norway had crops in the high Middle Ages that would disappear with the onset of cooling. The agricultural area with a settled population of farmers began to expand in the 9th and 10th centuries, and by the height of the warm period it had advanced on average 100 to 200 metres further

up the hillsides. The greater part of this cultivated land was lost after 1300 (Holmsen, 1961).

In Asia, too, plants migrated northward, and subtropical plants have never again been as northerly as they were in the 13th century. In 1264 they were growing several hundred kilometers further north than in the 20th century (De'er, 1994: 289-97).

The expanded habitat for heat-seeking insects also had implications for the spread of diseases. The *Anopheles* mosquito was present in many parts of Europe, and malaria was accordingly endemic as far north as England during the Middle Ages. Swarms of locusts repeatedly caused crop failures not only in Africa but also in Central Europe as late as the 14th century (Buckland and Wagner, 2001: 137-49).

There were key improvements in agriculture, in comparison with the early Middle Ages and even in Roman Antiquity. Crop rotation also helped to prevent soil exhaustion (Dhondt, 1968: 272-279). In *al-Andalus*, new crops were introduced from tropical and sub-tropical regions.

The adaptation was highly successful due to the warmer climatic conditions and the supply of water by irrigation. Whole new trades appeared, such as paper production, and during the 12th century windmills came to join the existing watermills.

In the Christian kingdoms of Western Europe, the new Gothic architectural style was developed, providing both brighter and lighter spaces. Huge windows allowed the sunlight of the medieval warm period to stream into the monumental cathedrals that were being built at this time.

Europe's population grew by leaps and bounds, reaching levels it had never seen before (Behringer, 2007: 80-81). The high Middle Ages were a time of new farmland and village creation even in remote areas, borderlands, and low mountainous regions (Schönwiese, 1995: 2). At this time Europe developed its characteristic landscape with high settlement density (Stoob, 1970). Most of the remaining irrigation systems still operating in Andalusia come from this period, when *al-Andalus* was ruled by the Muslims.

After the onset of the warm period, the progressive conquest of the Iberian Peninsula territories by Christian kingdoms was the first attempt at southward expansion by the northern kingdoms toward the south. The high Middle Ages were also the age of the Vikings. In the mid 9th century they conquered areas of the British Isles and settled in the Shetlands, Orkneys and Hebrides. They founded states in Ireland, conquered "Normandy" in western France in 911, and built a kingdom in Sicily. Vikings set up kings over the Slavs (Behringer, 2007: 80-81), and in the west some groups led by Erik the Red (c. 950-1005) sailed from Iceland to a much larger deserted country that he called "the green land". The Viking graves on the island are in an area where permafrost prevailed in the 20th century, though evidently not at the time of the burials. New lands to the west were discovered in North America from Greenland; today's Labrador in Canada, which was then given the name *Markland* ("land of forest"), *Helluland*, today's Baffin Island, and another island southward that was called *Vinland* ("Vineland"). About 1005 they began to settle in this new world, but the hostility of the

natives led to the collapse of these first European colonies in the Americas (Graham-Campbell, 1994).

2.4. *The Little Ice Age*

The period from the 13th to the 19th century, in which glaciers advanced in the Alps, Scandinavia and North America, was named the *Little Ice Age* in the late 1930s by the US glaciologist François Matthes (1875-1949), to distinguish it from the great ice ages (Matthes, 1950: 151-60). Hubert Horace Lamb (1913-1997) in England (Lamb, 1972/1977), Christian Pfister in Switzerland (Pfister, 1988), Rudolf Brádzil in the Czech Republic (Brádzil, 1990) and Rüdiger Glaser in Germany (Glaser, 1990: 129-44) have so clearly demonstrated climatic fluctuations in European history that their existence is now beyond all doubt (Pfister, 2001: 7-43). A decline in solar activity is usually regarded as the main explanation for the global cooling. The lesser number of sunspots between 1675 and 1715 was interpreted as a sign of reduced solar activity and this period is called the *Maunder Minimum* (Eddy, 1978: 226-8). People in the late-sixteenth and early-

seventeenth centuries were on average shorter than ever before or since in the past two millennia, comparable only to those in the critical times of the early fourteenth century (Würm, 1986: 101-8).

Ice records also indicate two clusters of intensified volcanism that coincide with the high point of the Little Ice Age. There are traces of the strongest volcanic activity since antiquity for the period between 1250 and 1500 and again between 1550 and 1700 (Hammer et al., 1981: 3-10). In the year 1452-1453 the explosion of the volcano Kuwae on Vanuatu preceded the “global chill” of the 1450 decade (Pang, 1993: 106), and five volcanic eruptions have been identified for the precarious decades between 1580 and 1600 (Palmer et al., 2001: 1953), sending ash that entered the stratosphere with such effect that solar radiation was reduced worldwide over the following months (de Silva, Alzueta and Salas, 2000: 15-24). Climatologists have worked out that eight periods with especially cool summers are linked to eight major volcanic explosions (Briffa et al. 1998: 450-455).

As in the case of the Medieval Warm Period, the Little Ice Age is related not to a constant cooling but to a dominant tendency. Along with a large number of cold and wet years there were also periods of “normal” weather and even some years of extreme heat (Behringer, 2007: 85-86). A distinct climatic period began around the year 1300 in the Atlantic North that had little in common with the warm high Middle Ages; and in the second decade of the 14th century began the Little Ice Age (Alexandre, 1987: 807f). A series of cold winters between 1310 and 1330 happened in Europe, notably in the northern region, that led to the Great Famine of 1315-1322 (Behringer, 2007: 103-106). At the same time, the second decade of the 14th century had the years with the most rain in the whole of the past millennium (Alexandre, 1987: 781-5). The harshest winter of the decade came in 1317-18, when the cold lasted from late November until Easter, and excessive rainfall alternated with periods of drought in Europe (Glaser, 2001: 65). A succession of difficult years happened in the mid-1330 decade. The summer of 1342 brought one of the worst

environmental disasters of the past thousand years. Intensive rainfall caused rivers to overflow in July. The high water carved deep gorges and permanently changed the landscape. In 1343 there were again long periods of rain in July, August, and September. In 1344 great aridity and drought reduced the size of the harvest (Bergdolt, 2008: 212). The adverse climate of the 1330 decade affected the whole of the northern hemisphere, and a bit later the Black Death plague of 1346-1352 struck Europe after many centuries of absence in this continent (Behringer, 2007: 107-109). Thirty percent of the population succumbed to it, with regional death rates between 10% and 60% (Bulst, 2003: 1915-18).

Even if the Little Ice Age was a worldwide phenomenon, it was not always completely synchronous (Grove, 2001, 53-82). This term sounds somewhat inappropriate for arid and tropical regions. In West Africa and similar regions near the Equator, it was not so much the cooling as the irregularity of rainfall that posed a threat. As in parts of

the Mediterranean, drought was the main problem. The climate zone in which agriculture could be pursued became dramatically smaller during the early modern period, because the Sahara desert and the Sahel zone moved several hundred kilometers south. So increased aridity may be regarded as the typical feature of the global cooling in some meridional regions, and in the case of the Iberian Peninsula, diverse historical accounts suggest that with the increasing cooling, the south of Spain was also drying up (Olagüe, 1950: vol. 4, ch. 25).

At this time anthropogenic changes were introduced (Behringer, 2007: 102-103) that led to an overexploitation of nature. In the British Isles, Spain, Italy, Dalmatia or Greece, Asia Minor, and North Africa scarcely any forest was left. This deforestation had well-known consequences: lowering of the water table (which especially in the Mediterranean basin intensified the problem of aridity) and greater susceptibility of cultivated land to soil erosion and flooding (Braudel, 1975: 267ff).

3. BUILDING AGAINST A HARSH CLIMATE IN THE ISLAMIC WORLD

In an unfriendly environment with hot severe climatic conditions the most effective shelter is the courtyard house (Ragette, 2003: 80) where different mechanisms can be improved in order to achieve comfort for his occupants.

“Perhaps the most satisfying architectural response to the continuously dry topics is the Mediterranean residence centered on a courtyard. With a meager but well-developed water supply, the courtyards feature fountains, ponds, and growing plants for both evaporative cooling and for aesthetic enhancement. Individual homes are connected by narrow streets and shared walls. By day, one or two narrow, tunnel-like entrances from the street provide ventilation through cool ports. But it is in the fine-tuning of the courtyard environment –its optimization of wall heat resistance, ventilation rate and evaporation rate– that is most satisfying.” (Lowry and Lowry: 1989).

3.1. Orientation and Flexibility

The first response to local climate is orientation in reference to sun or wind. The sun might be the principal source of comfort or discomfort, thus determining the orientation of buildings and spaces if possible. The exceptions are Islamic religious buildings with their orientation toward Mecca, and other site-imposed constraints, such as orientation toward a view or for defense purposes.

While the Greco-Roman civilization rationally planned whole cities with street grids for maximum shade and breeze, the flexibility of Islamic house design allows individual orientation solutions. It enables the inhabitants to live in those parts of the house that are most comfortable in terms of temperature and ventilation. This could be a reflection of a nomadic background, and as a result it has been described as horizontal and vertical nomadism (Ragette, 2003: 84-85) (Image 3.1).

The first response is usually seasonal, taking advantage of different orientations of rooms. In the cool season, sunshine is the main heat factor available, so the

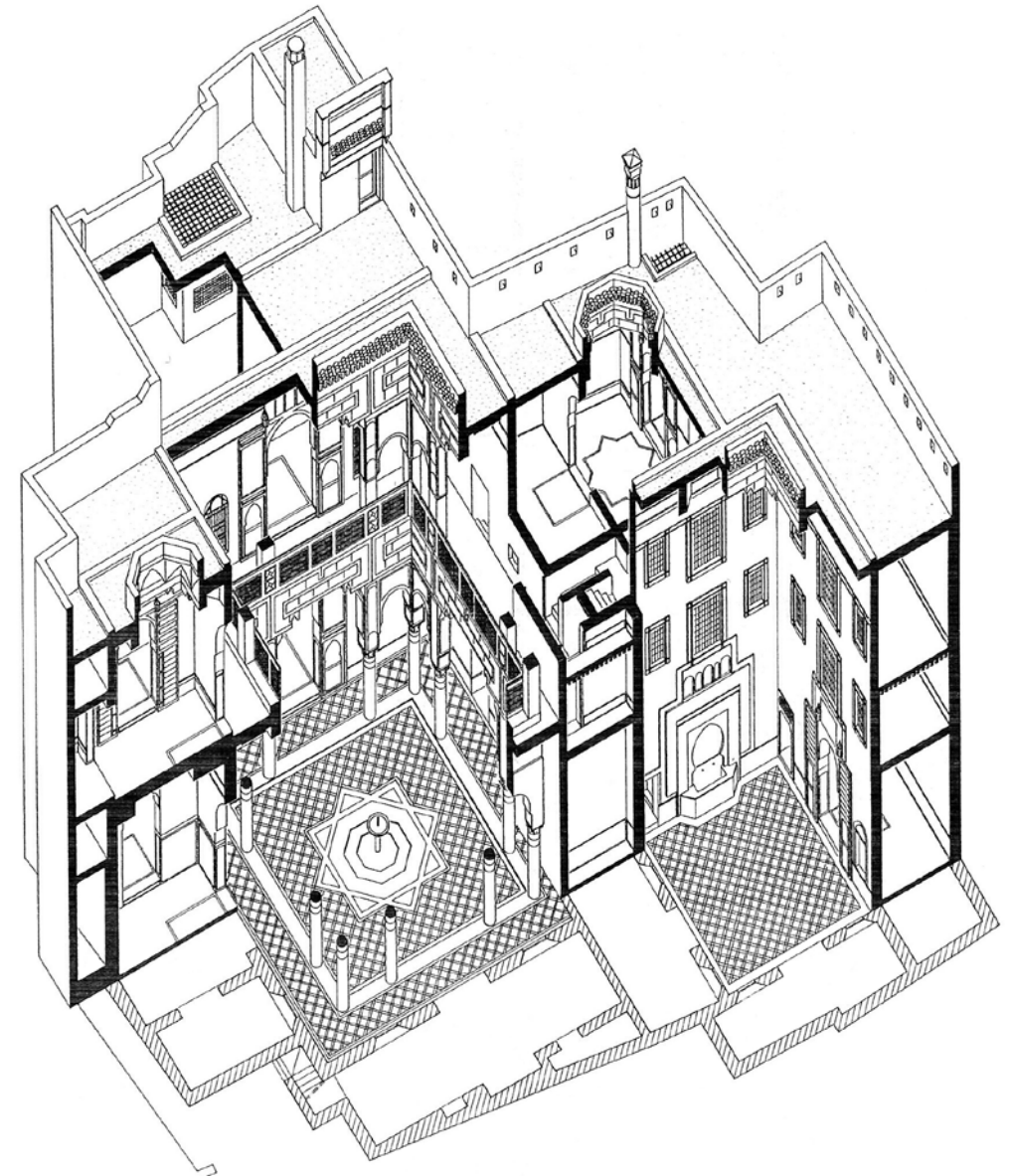


Image 3.1. Fez (Morocco), sectional axonometric of house Lahlou (Bianca, 1991).

dweller should move to south-facing rooms with low ceilings and large windows to let the sun's rays enter and keep them warm. In the summer a high and open north oriented room such as the *iwān*, *qa'a*, *qubba* and other main rooms will serve best

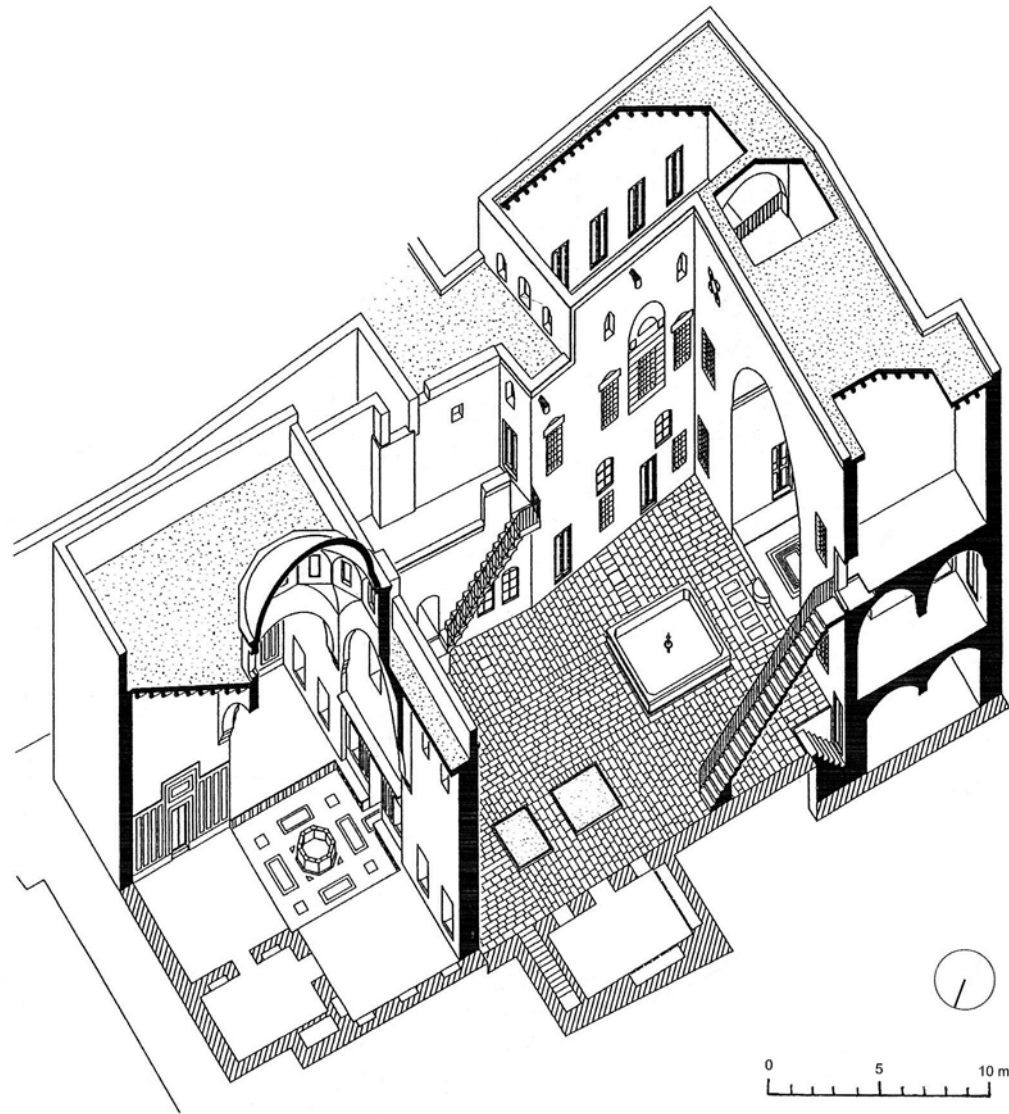


Image 3.2. Aleppo (Syria), sectional axonometric of house "C". (Bianca, 1991 and Ragette, 2003: 166). The courtyard with the high windows above the *qa'a* is the source of light and air.

(Image 3.2). Under spacious rural conditions people live either in a winter house with solid walls or a summer house with screen walls

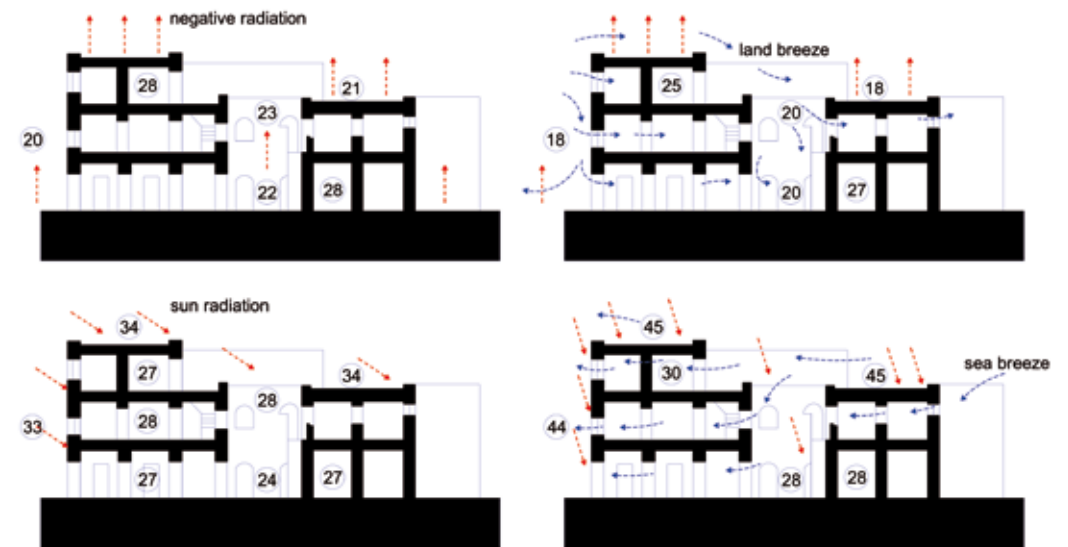
of reeds or pierced walling. A simple alternative to the summer house is an open sleeping terrace on the roof.

This applies to hinterland settlements, particularly in regions with a pronounced difference between summer and winter climate, also characterized by large diurnal temperature differences. They are a result of the intense solar radiation during the day and quick cooling down under the cloudless night sky. Mass-construction of exterior walls of mud, rammed (compacted) earth, adobe, brick, stone or any combination of them will not only insulate against the heat of the day, but delay heat transmission due to its thermic inertia and store heat for cold nights and mornings.

Houses close to beachfronts tend to open toward the beach to take advantage of the daytime breeze. Open summer rooms will be in front, and winter accommodation behind the courtyard in the back.

The most effective response to temperature change is vertical nomadism. In extreme climates, nights are spent on the roof, mornings on the lower floors and excessive afternoon heat is avoided in the basement. This strategy is based upon cool sky radiation at night and the fact that warm air rises while cool air collects in low spaces. Even the

Image 3.3. Temperature variations for the average summer day-night sequence of insolation and ventilation in a traditional Gulf house in the Emirates (after Ragette, 2003: 85).



closing and opening of windows and doors is done judiciously, either to permit or inhibit circulation of air (Image 3.3).

Seasonal shifting from ground to first floor at the onset of summer was a habit in humid seafronts, and it resulted in a duplication of floor plans. In coastal areas with nearby mountains people take to spending the hottest month in places of high altitude.

In many cases, the orientation of the courtyard's walls depends upon that of the street outside and/or the shape of the plot. In other cases, the orientation prevails over other variables, and a very irregular site surrounds a square courtyard oriented to the cardinal points (Reynolds, 2002: 9).

3.2. Shading

The desert tent is primarily a shading device, and tent-like structures with canvas were also provided in urban areas as effective shades. The further north or south of the equator, the bigger the difference of sun angles between winter and summer solstice. This allows winter sun to penetrate more deeply in south-oriented rooms at

a time when warmth is needed. During the late spring, summer and early fall, shading against direct sun is desired in most parts of the Islamic world. Colonnaded or arcaded porches and peristyles give shade to passages and walls, and also protect against the rain and the cold when necessary.

Which side of the courtyard receives direct sun and at what time of the day determines where and when maximum daylight and optimum thermal comfort is available for people and plants. In rectangular but non-square courtyards oriented to the cardinal compass, those that are elongated east-west and have their longer sides face north and south, direct sunlight in summer can be prevented from entering the longer sides with shallow overhangs, leaving the openings available for wind. The shorter sides, however, get strong direct sun across the length of the courtyard in the morning or evening of summer. In winter, when strong sunlight is welcome, it is almost absent (Reynolds, 2002: 9-13).

When the axis is north-south the longer walls face east-west. There are problems with summer

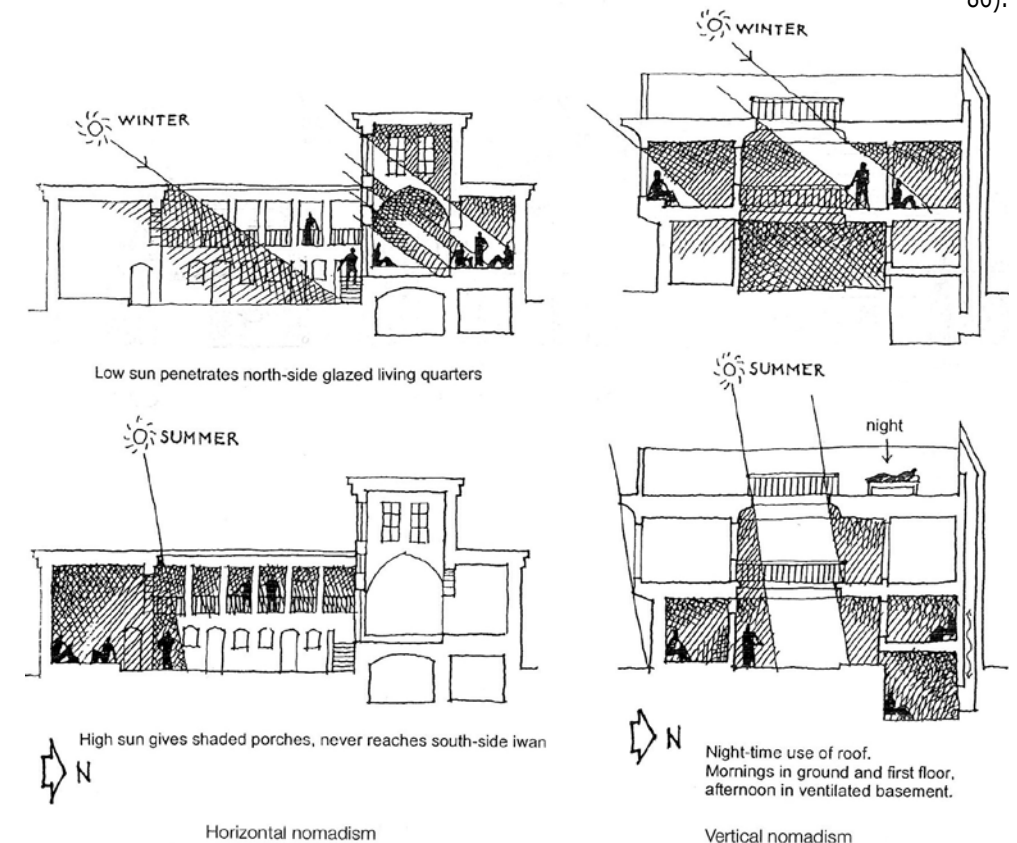
sun in morning or afternoon, but one long wall partially shades the other at the earliest and latest hours. Meanwhile the shorter side (facing the equator) gets direct sun across the length of the courtyard around noon in winter and the walls receive its warmth (Image 3.4).

The optimal orientation depends on the use of the long or short sides, and whether winter heating

or summer cooling is the greater need.

Since buildings are predominantly closed to the outside in the Islamic regions, shading elements on the façades play a mirror role and visual screens act also as shades. Trellises and other devices such as sun-breaks became primary design features not only for the preservation of privacy, but also for sun protection (Ragette, 2003:

Image 3.4. Shading in north-south dwellings (Cejka, unpublished manuscript and Ragette, 2003: 86).



86). That can be seen in the buildings located in the Menteşe Mountains (southwest Anatolia) with verandas (Aran, 2000: 96-100), protected by wide eaves and wooden trellis of different high (Image 3.5). Such *loggias* are usually placed before the entrance of south-facing rooms, and are where much of the daily household activity takes place, sometimes including a fireplace for cooking when the weather is mild. This area is sensitive to the Mediterranean marine climate.

Image 3.5. Open veranda in front of a room of a Menteşe Mountains' house, sunny in winter (above) and shaded in summer (down) (Aran, 2000: 98-99).



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This climate requires buildings constructed in a manner that ensures effective ventilation, protection against extreme summer temperatures, and resistance to rain storms. These kinds of verandas are spaces attached to rooms atop granaries, open at the sides and roofed above.

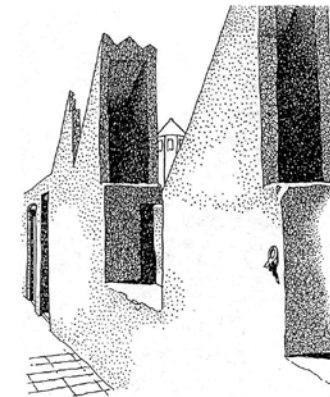
3.3. Ventilation

The interior courtyard is an excellent modifier of hot and dry climates, being an air-well that collects dense, cool air at night. Protected from the morning sun, all surrounding spaces stay cool till well into the day. When the sun reaches the courtyard, the air heats up and rises, creating convection currents and cross-ventilation, particularly when the surrounding spaces have secondary ventilation openings from adjacent narrow and cool alleys.

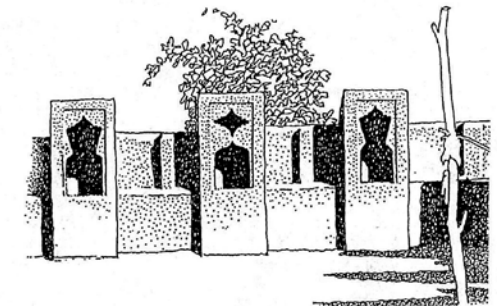
Ventilation is most important in humid coastal situations with little drop of temperature during the night. The higher up one is, the more breezes can be enjoyed: from the sea during the day, from the land during the night. Upper-

floor rooms have large screened openings down to the floor heat. The roof itself looks like equipped with inner shutters, to close the room against daytime heat. The roof itself looks like equipped with inner shutters, to

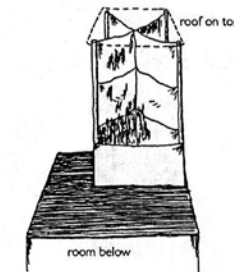
Image 3.6. Wind-scoops and wind-towers (Cejka, unpublished manuscript; Coles and Jackson, 1975; Damluji, 1998 and Ragette, 2003: 87, 89, 90).



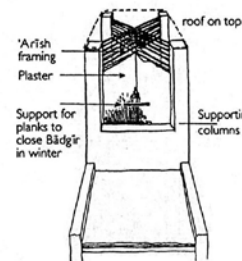
Wind-scoops parallel to building wall



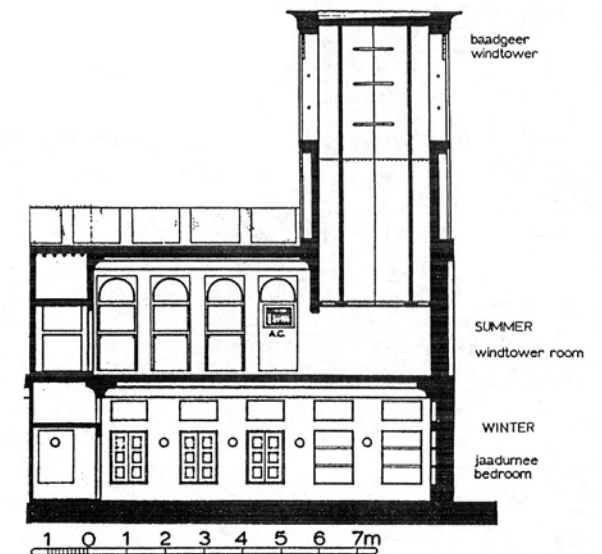
Decorated wind-scoops in Baghdad



Wood and canvas windtower



Lath and plaster windtower with masonry corners



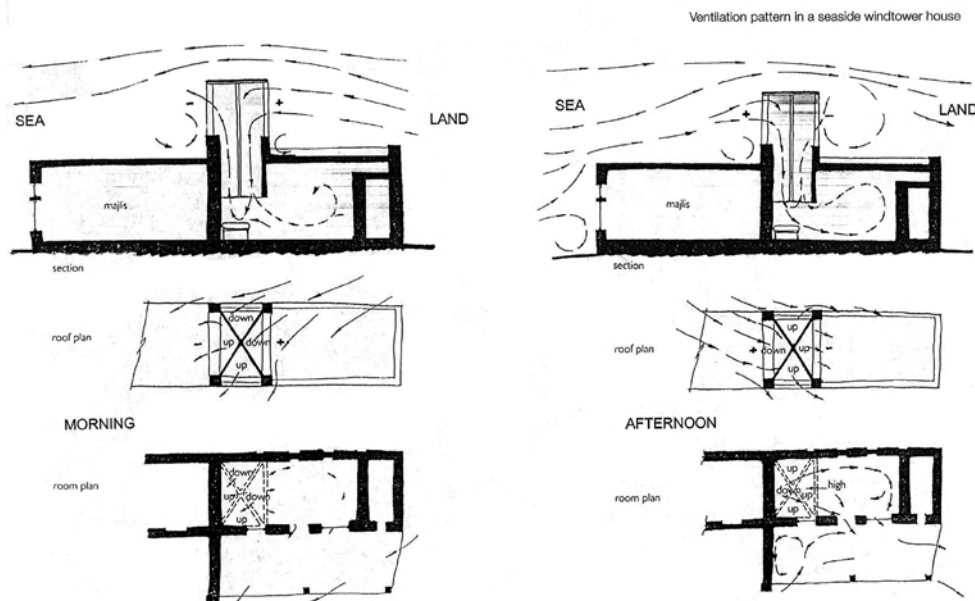
another story, being screened to the outside.

The most remarkable ventilation devices are wind-scoops and wind-towers (Image 3.6). In the first one ventilation flues are set above the roof to catch cool and clean air. They face the prevailing wind direction and divert air to the rooms below in a reverse chimney action. Through the rooms the air passes into the courtyard, feeding the convection cycle. In certain cases of Iraqi architecture, different floors receive independent wind-scoops which are decorated when they open to the roof terrace. When

the prevailing wind is parallel to the wall they have tall, narrow intakes.

Multi-directional wind-towers are the trademark of Gulf architecture. Introduced from southern Iran, they range from simple wood framed canvas screens to monumental towers. Their X-plan catches the breeze from any direction and leads it into the room below, while also sucking it out from the leeward side, which increases the ventilation pull (Image 3.7). This effect provides fresh air all the time. If the ambient air has less than 60% relative humidity, the cooling action can be improved

Image 3.7. X-plan wind-catcher in Oman (Damluji, 1998 and Ragette, 2003: 89).



by the evaporation effect of wet canvas, or earthenware jugs and fountains being placed in the path of the air. During winter the wind-tower is either closed at the bottom or the room served by it is not used (Ragette, 2003: 84-89).

In some parts of the Gulf region, whole parapet walls along the roof are turned into wind-scoops by making them double-walled, to direct the air to the screened lower part of the roof, or the room below. In Cairo, large wind-catchers ventilate principal living rooms or *qa'as* (Image 3.8).

4. COURTYARD HOUSES

The courtyard house represents a constant feature of domestic architecture in most Muslim regions. It was, however, developed in different ways as influenced by existing local traditions, construction materials and environmental factors. The courtyard houses of *al-Andalus* and North African *medinas* display different characteristics than those of Egypt, Syria, and Iraq as they feature the most formalized configurations with an absolute centrality of the courtyard (Sibley, 2006: 49).

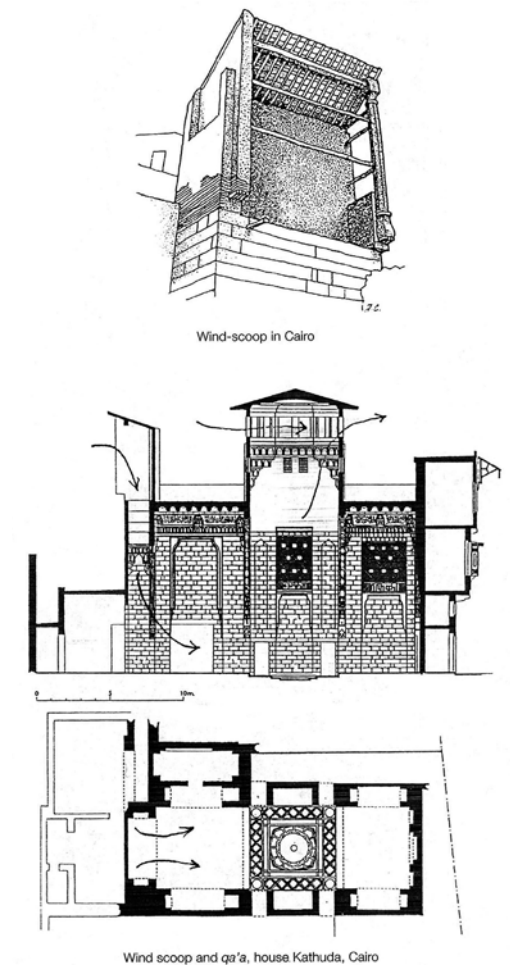


Image 3.8. Wind-catcher in Cairo (Cejka, unpublished manuscript; CNRS, 1982 and Ragette, 2003: 88).

They work well in hot and dry climates, especially not square but more narrow and deep in order to create shade from the summer sun. Their disadvantage in cold winters is the limited

access to sun and heat, and in humid summers the lack of wind, but these can be counteracted with different devices, so they are found in nearly every climate zone (Reynolds, 2010: 145).

4.1. The Sequence from the Outside to the Courtyard

Contrast is an essential ingredient of courtyard aesthetics, beginning with the first transition from the heat, noise and smell of the street to the cool, dark and quiet of the covered entranceway from street to courtyard. After that is the courtyard with its contrasts of light and shadow, open space and vegetation, dry and wet surfaces, still and flowing water (Reynolds, 2002: 4-5).

Variations on the “bent” path are typical of Islamic cultures (Image 4.1). Its indirectness ensures visual privacy from the street.

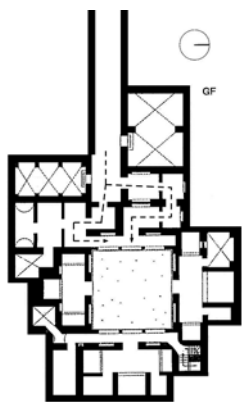
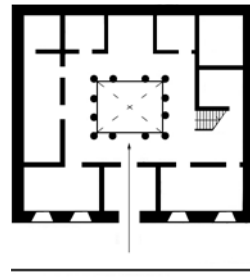


Image 4.1. Double bending entrance in the house Bairam Tourki (Revault, 1967/71 and Ragette, 2003: 130).

Image 4.2. A typical Hispanic arrangement of a house or palace, with the *zaguán* pointing to the courtyard's center (Reynolds, 2002: Chapter 1, 4-5).



The “axial” path from the street to the courtyard is prominent on the north side of the Mediterranean. It allows direct passage and

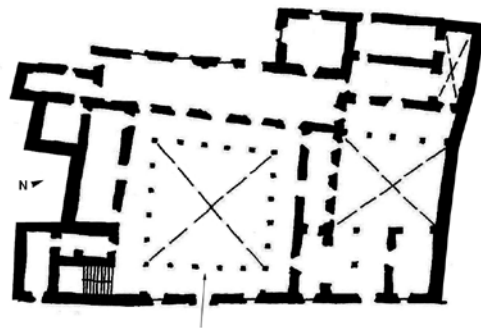


Image 4.3. The arcade is the only transition from street to courtyard in this house from Seville (Spain) (from Collante de Terán Delorme and Gómez Estern, 1976).

direct views from the street, often leading straight to the courtyard's center (Image 4.2). This was used in the Roman *domus* and was conserved throughout Hispanic cultures.

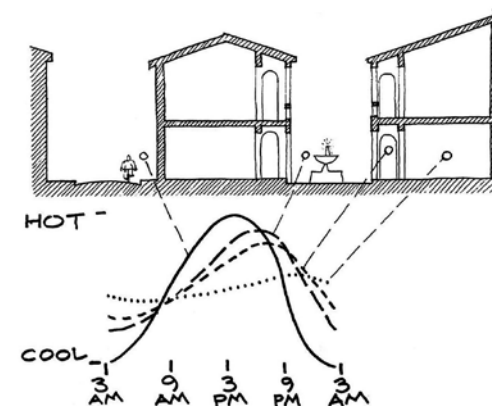
An abrupt departure is a direct gate from street to courtyard, where the courtyard and street

are adjacent (Image 4.3). This style of courtyard may take on the role of the walled garden, or even the front yard of a well-fenced home, depending on the number of openings in the street façade.

4.2. Taming the Climate

The contrast between less and more comfortable spaces within the sequence of open countryside, street, “*zaguán*”, courtyard, arcade, and room, greatly increases satisfaction with the latter, the most private and personal space (Image 4.4). The most dramatic thermal contrast is often between the street and the courtyard, and it is reinforced by the change from public to private.

Image 4.4. Sketch with the daily temperature fluctuations in a courtyard house and its surroundings in the hot season (Drawing by Michael Cockram, in: Reynolds, 2002: Chapter 5: 79).



Thermal comfort in traditional hot-climate courtyard buildings depends greatly upon the thermal mass of the building for the extent that the temperature fluctuates and at what hours it reaches highs and lows. Second, it depends on the personal involvement of the building's occupants, whose actions are often called thermal sailing (Reynolds, 2002: 78-93). This includes watering the courtyard, opening and closing shading devices and windows, and adjusting their own clothing and activity level.

Courtyards represent and attempt to control the forces of nature. As pockets of space that are open to the sky, courtyards intensify some aspects of the climate, such as daylight, and dilute others, such as the wind.

The patio provides an extensive exposure to the sky, which is very cold on clear nights, stressing cold in winter's long nights. It also emphasizes heat in the hot season, because when the sun is high in the sky at noon, the widest surface of the patio is heated. In this hour the floor and several walls are sunny, with only the north-facing wall remaining a reliably shaded surface. This

heat emphasis is partially offset at night, when clear skies are coldest.

Thermal comfort can be readily controlled with movable shading covers over the entire courtyard, window awnings, or movable glazing in the openings of arcades. In recent times diverse strategies have been introduced in the managing of traditional courtyards, such as glazing of arcades, covering the courtyard with a skylight, dividing the courtyard between occupants,

walling in one or more arcades, encroaching upon the courtyard's open space, and adding upper floors around the courtyard (Reynolds, 2010: 145).

5. NASRID HOUSE TYPOLOGY

From 1232 to 1492, the last *Nasrid* kingdom, established in the southeast of modern Spain and the last one with Islamic roots in the Iberian Peninsula (Image 5.1), developed a remarkable archetype of courtyard-houses.

Image 5.1. *Nasrid* kingdom (1232-1492) in the southeast of the Iberian Peninsula, and its border evolution (Ladero Quesada, 2001).



As with its precursors from the *Almohads*, *Taifas* and *Caliphate* periods (Image 5.2), in *Nasrid* architecture all domestic life revolved around the patio, which was the center of family life. It was the place for receiving light and air and the space that linked the different rooms of the house (Image 5.3). It also had bioclimatic architectural functions in regulating the building's microclimate naturally. They produced a kind of rectangular courtyard with porticoes on the shorter sides, closed exteriors and access through bending doorways.

already formalized by the 10th century in *Madinat al-Zahra'* (Córdoba) (Image 5.4). The main variations were introduced in the provision of pools and water reservoirs flowerbeds, raised walkways and galleries in the courtyard. In the first half of the 13th century, when the *Almohad* Empire drew to end, there was a tendency to decrease or eliminate the patio garden. In post-*Almohad* Murcia (Image 5.5) and during the *Nasrid* period (Image 5.6) a pool model became popular, which was elongated along the direction of the longitudinal axis, occupying the center and, at times, approaching the two opposite arcades. This arrangement

In *al-Andalus*, the new style was

Image 5.2. Examples of *Caliphate* (10th century), *Taifas* (11th century) and *Almohad* (12th century) residences (Almagro Gorbea, 2008: 35, 40 and 46).

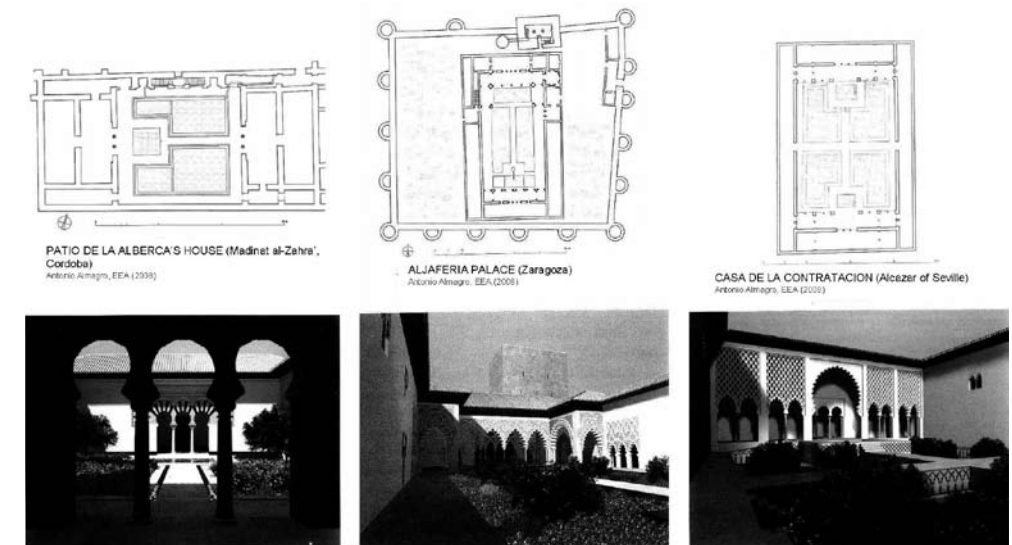


Image 5.3. Examples of Nasrid (1232-1492) residences in the Alhambra (Almagro Gorbea, 2008: 53-54).

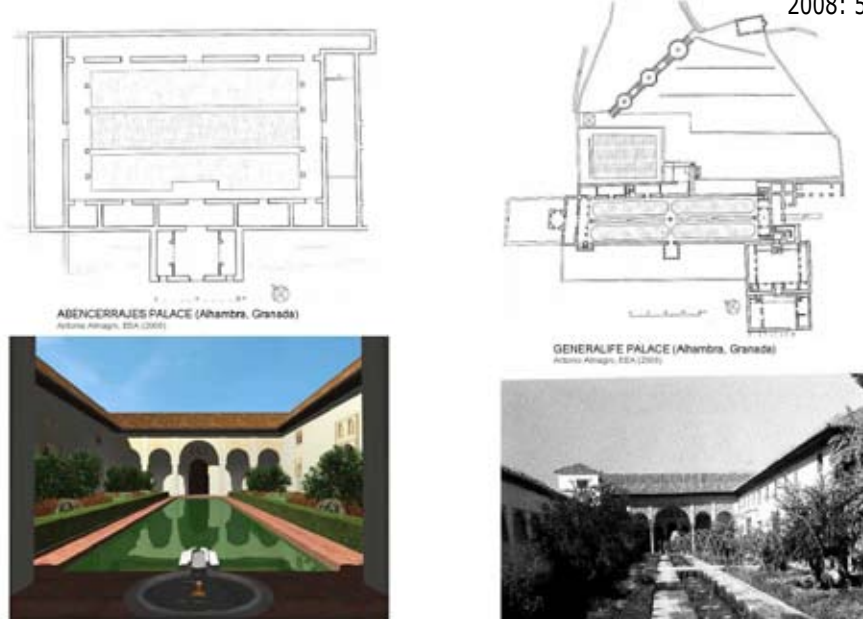


Image 5.4. Plan and virtual reconstitution of *Madinat al-Zahra'* (10th century) (Almagro Gorbea, 2008: 53-24).

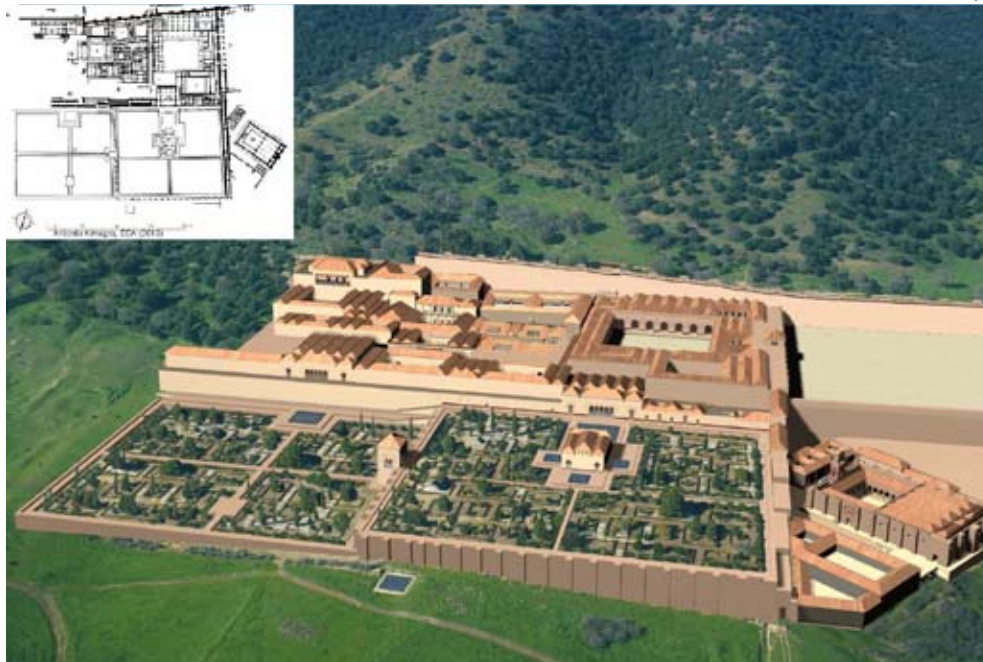


Image 5.5. Map of *al-Qasr Dār al-Sagīr* (Ibn Hud, 1228-1238) in Murcia (Spain) and today's view of Santa Clara's Monastery, built in the same plot (Navarro Palazón, 1995: 177-206).



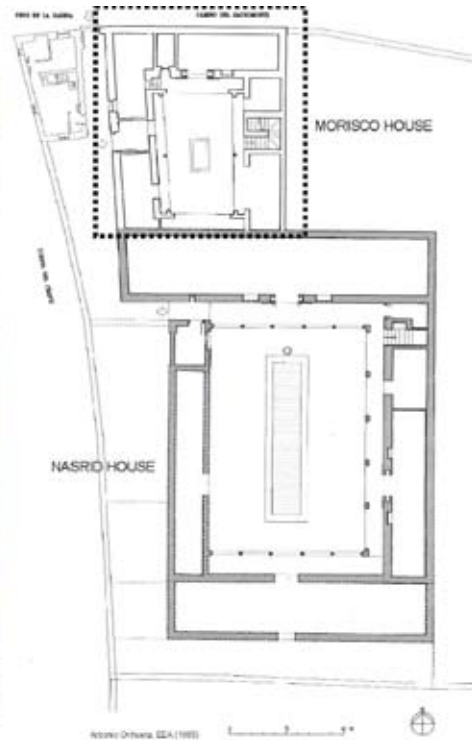
Image 5.6. Pools and bending entrances in the Partal Alto palace and its surrounding in the Alhambra (14th century) (after Orihuela Uzal, 2011: 129-143)

of rectangular courtyard with north-south orientation providing maximum entry of sunlight in winter and shade in summer is an adaptation to a climate with short cold winters and long hot summers. Protection against excessive sunlight could be achieved by using climbing plants trained along trellises usually starting from one corner of the patio. The last refuge of *Andalusi* culture, the houses of *Morisco* society, developed in the first half of the 16th century a well-defined residential type, derived from

basic characteristics of *Nasrid* courtyard-houses. Courtyards were established in which the pool was on a more modest scale, tending to be square (Image 5.7).

It is also possible to detect a process of evolution in shaping the gateway to the main room. It began with the triple openings, followed by geminate openings in the *Almohad* period. The final evolution to a single entrance occurred in the post-*Almohad* Murcia, becoming fully established in *Morisco* times. This reduction in

Image 5.7. El Feri *Morisco* house in the Albaicín of Granada (Orihuela Uzal, 1996: 309).



access openings may also have had a bioclimatic component, because through it and the latticed windows located over it an energy exchange is produced between the courtyard and the main room of the house.

The two side spaces were always lower in elevation than the main rooms. Sometimes there is only one secondary side of the courtyard, where they would place the kitchen and other ancillary parts such as the latrine, warehouses, barns, storage areas, and stairs. The kitchen and barns almost always had a room above, to be used in winter, taking advantage of the heat energy provided by them from the ground level. The existence of a second floor in these side spaces allowed the eaves to be level around the perimeter of the courtyard, thus enhancing the shaded areas. The upper floors often had little height, a fact that favored heating in winter. Its occupants sat on the floor on mats or carpets, which explains the common existence of small windows to the patio with the lower sills almost at ground level. Due to their reduced space and limited openings to the exterior with exposure to the sun, these units would be best

used in winter. Main rooms were covered with carpets, cushions and pillows. The use of these along with tapestries on the floor and walls enhanced the heat and sound insulation inside these rooms (Image 5.8).

During the 14th and 15th centuries there was a gradual increase in the height of the houses, with widespread use of higher stories (Image 5.9). This meant doubling the height of the houses, as it reproduced the pattern of the floor below, allowing for diversification in seasonal use. The upper floors of the main rooms also caught more sunlight by being open by the portico to the south. Among other political and social causes this was probably a response to climatic cooling conditions at the end of the Middle Ages, as the

Image 5.8. Tapestries and carpets in a main room of a *Nasrid* palace in the historicist picture "Salida de la familia de Boabdil de la Alhambra", painted by Manuel Gómez-Moreno in 1880.



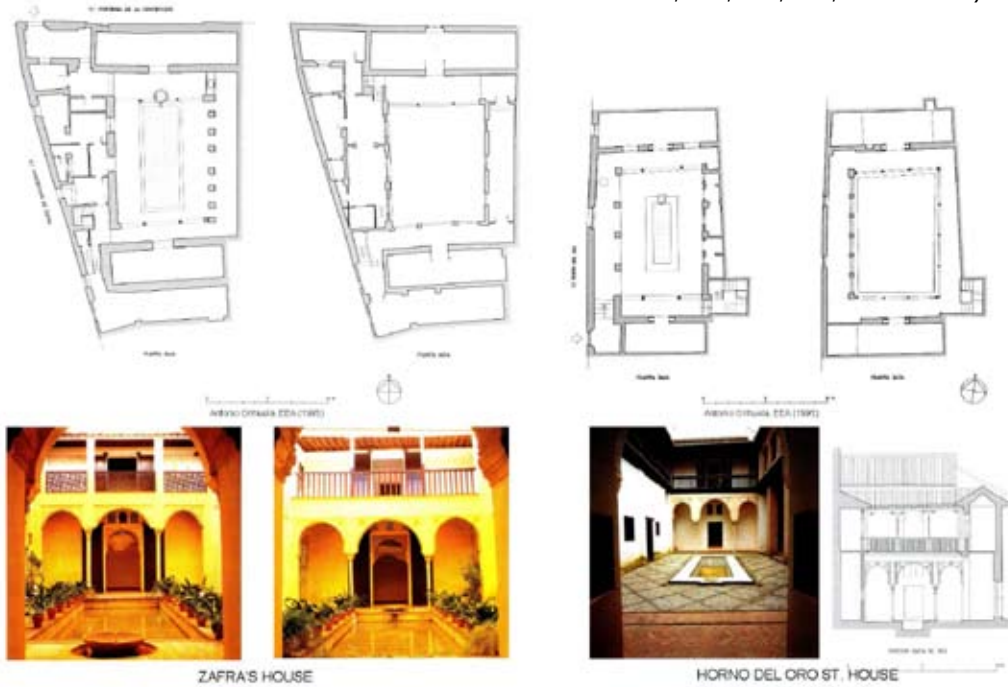
arcaded galleries established a first element of thermal protection in residential rooms. This model would have been influenced by the monastic cloisters and domestic architecture of the societies in the Christian Spanish northern kingdoms (Image 5.10), which adopted provisions for adapting architecture to harsh temperatures before those in the south did.

The residences developed by the medieval Islamic culture

were adapted to the particular conditions and climate of each region in which they settled. The solutions they arrived at, refined over the generations, often achieved appropriate layouts for a harsh climate and surroundings. The houses were constructed without openings or with some small lattice window to the street, while inside they opened out to the private patio that constituted a true "oasis or inner paradise."

The house is developed around

Image 5.9. *Nasrid* urban houses in the Albaicín of Granada with higher stories (Orihuela Uzal, 1996: 282, 286, 287, 296, 297 and 300).

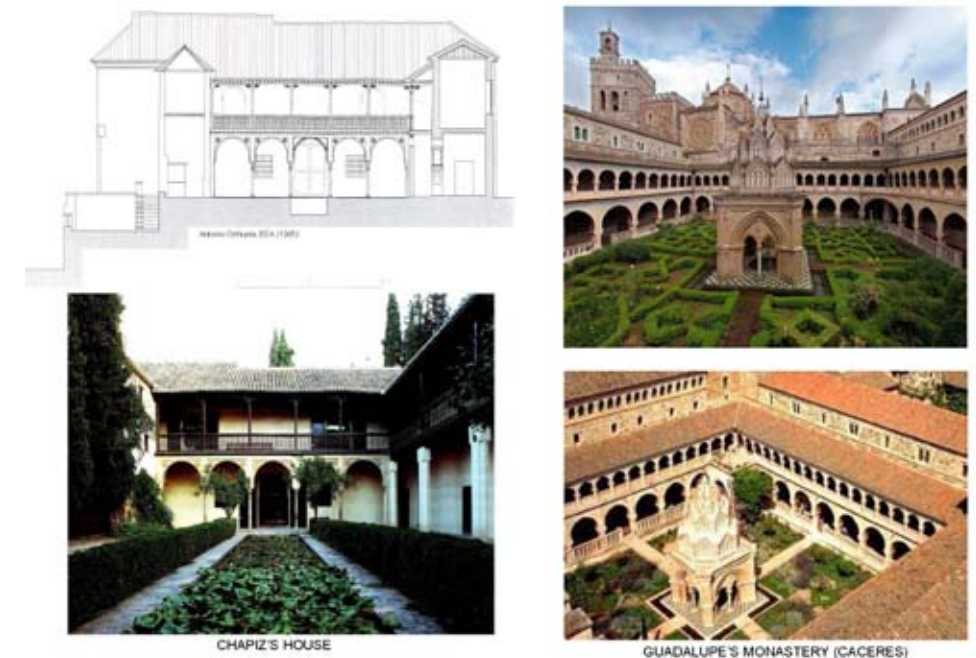


the patio, which is private and has a symbolic character within the Islamic world. Houses and palaces did not display great differences from a typological point of view. Only scale devices (often 10:1) and decorative features differentiate a palace from a house (Image 5.11).

The common characteristics of *Nasrid* architecture are as follows (Orihuela Uzal, 1996: 19-40): The corridor from the entrance to the street had a bend protecting the

inner privacy of the patio, which acted as a lobby. According to the social category of the owner, the patio had two, one or no porticoes in its smaller sides. Centered in each one of the galleries was an important poly-functional room, derived from Roman *triclinium*. In palaces and the more important houses, the available space allowed for flexibility in alternating the use of domestic chambers, depending on the hour of the day and the season of the year. The same scheme was also repeated

Image 5.10. El Chapiz *Morisco* house (16th century) with remaining of a previous *Nasrid* palace in the Albaicín of Granada (Orihuela Uzal, 1996: 310 and 313) and views for the courtyard of the Guadalupe's Monastery in Cáceres (Spain).



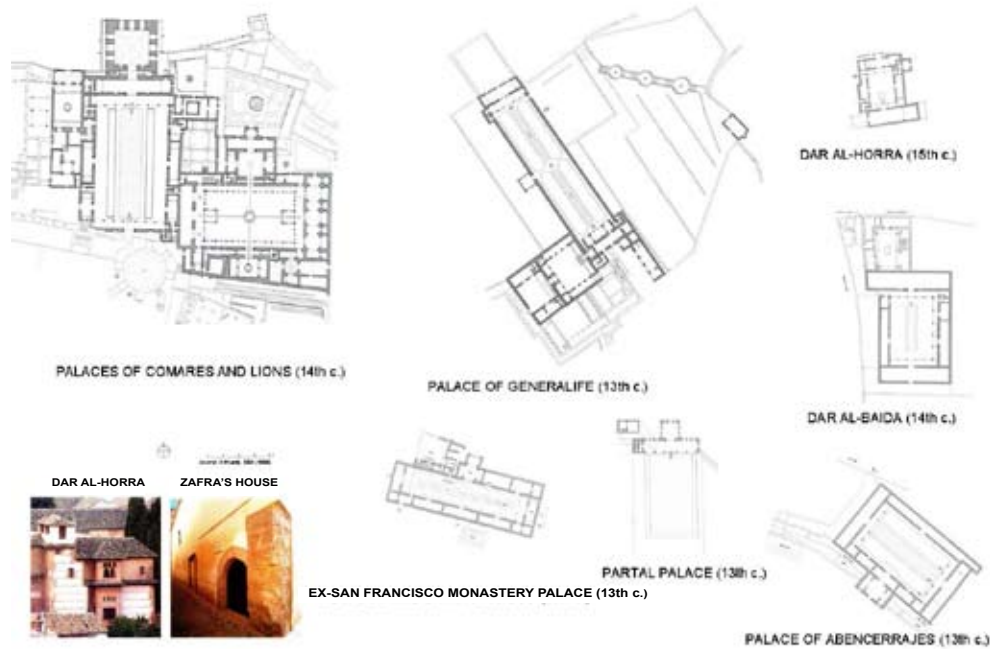


Image 5.11. *Nasrid* palaces and houses from Granada with the same scale and orientation (after maps from Orihuela Uzal, 1996: 53, 60, 74, 83, 104, 200, 231, 234, 283, 309).

on the upper floor, although the bioclimatic features were often reversed. So, while the lower floors served to lessen the heat of the day, the upper rooms were warmer, their smaller size making them easier to heat. In the early Islamic medieval period, houses would normally have only one floor. However, the increase in population density in cities that resisted the Christian advance necessitated the need for more space, and so a second floor was added. This fact could also have been influenced by colder climatic conditions in 14th and 15th centuries.

6. BIOCLIMATIC DEVICES OF NASRID ARCHITECTURE

There is no single way to interact with climate factors in architecture, but *Nasrid* buildings were the result of an intuitive process of background experimentation, developing what today we call effective “bioclimatics skills,” in which very precise and methods were fine-tuned, learning from previous architectonic models.

The interior southeast of the Iberian Peninsula has a Mediterranean climate with semi-arid character in many regions (Image 6.1). Dry

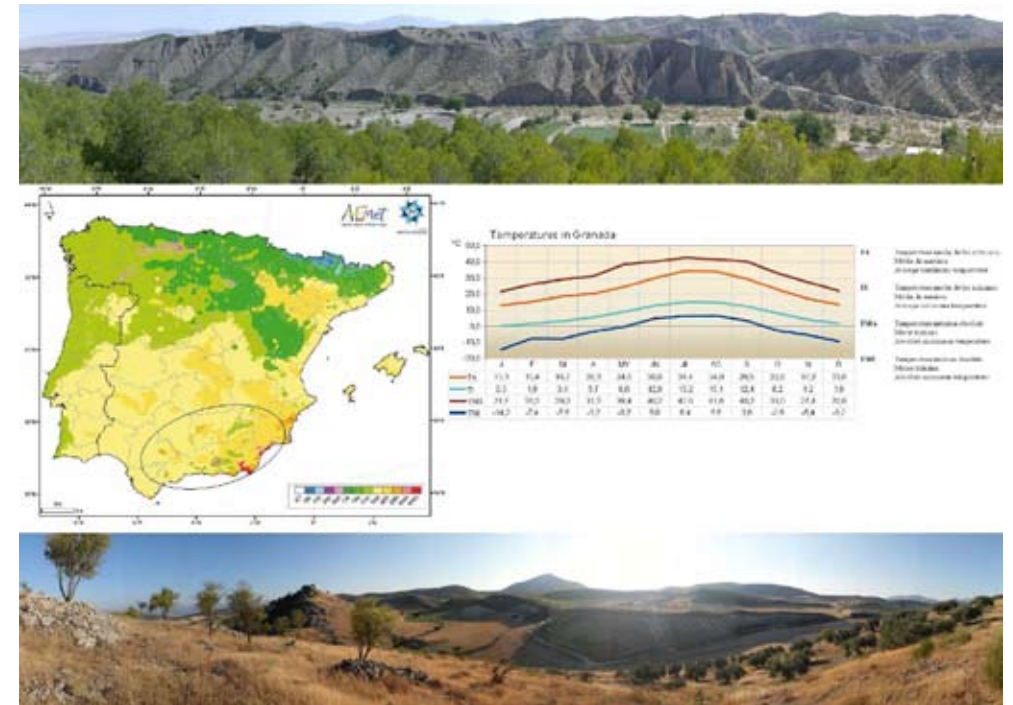


Image 6.1. Modern climate (Agencia Estatal de Meteorología, Ministerio de Medio Ambiente y Medio Rural y Marino, 2011: 18 and 32) and semi-arid character in some interior regions of the southeast of the Iberian Peninsula.

air is accompanied by extreme temperatures, especially in the long hot months of summer. Concentration of rain in cool to cold winters, warm to hot dry summers, and intensive solar radiation especially in summer, are the main characteristics of the Mediterranean climate. The Mediterranean continental climate is distinguished by its large ranges of diurnal temperature and fluctuating relative humidity. In general, strong westerly and southwesterly winds dominate.

Solar radiation is intense especially in summer. Winter temperatures are usually above freezing point. Average rainfall is small, but variable; it increases in winter, in contrast to dry summers. In the Mediterranean marine climate, the diurnal temperature range is small. Vapor pressure is high in summer, and wind velocity usually is low, and wind direction is westerly and southwesterly. The amount of precipitation depends on latitude and decreases from north to south. Rains are

concentrated within periods of a few days of high intensity, and are accompanied by storms of high wind velocity. The Mediterranean marine climate requires that buildings be constructed in a manner that ensures effective ventilation, protection against extreme summer temperatures, and resistance to rain storms (Givoni, 1967: 357-358, 362).

Al-Andalus architecture harmonizes with the surroundings to obtain from them the greatest benefits for the comfort and enjoyment of the inhabitants (Image 6.2). So, the buildings open onto fresh shaded gardens, keeping out the summer sun while taking advantage of the winter one. They ventilate the interiors to cool and remove the hot air. They are insulated with heavy walls



Image 6.2. View of the Alhambra from the orchards of the *al-munya* of the Generalife.

that reduce thermal fluctuations. Thus there is a set of passive systems that react to an active outer atmosphere. In this sense, this architecture is environmental or bioclimatic.

Natural light is manipulated and deliberately controlled in *Nasrid* architecture (Image 6.3). The light intensity and the high number of hours of sunlight experienced in those zones contrasts with the low illumination of the interiors, but there is no shortage of examples of attempts to bring light and its consequent calorific energy into certain main rooms.

In order to fight against the cold, *Nasrid* architecture is normally composed of thick massive walls providing insulation due to their high thermal inertia

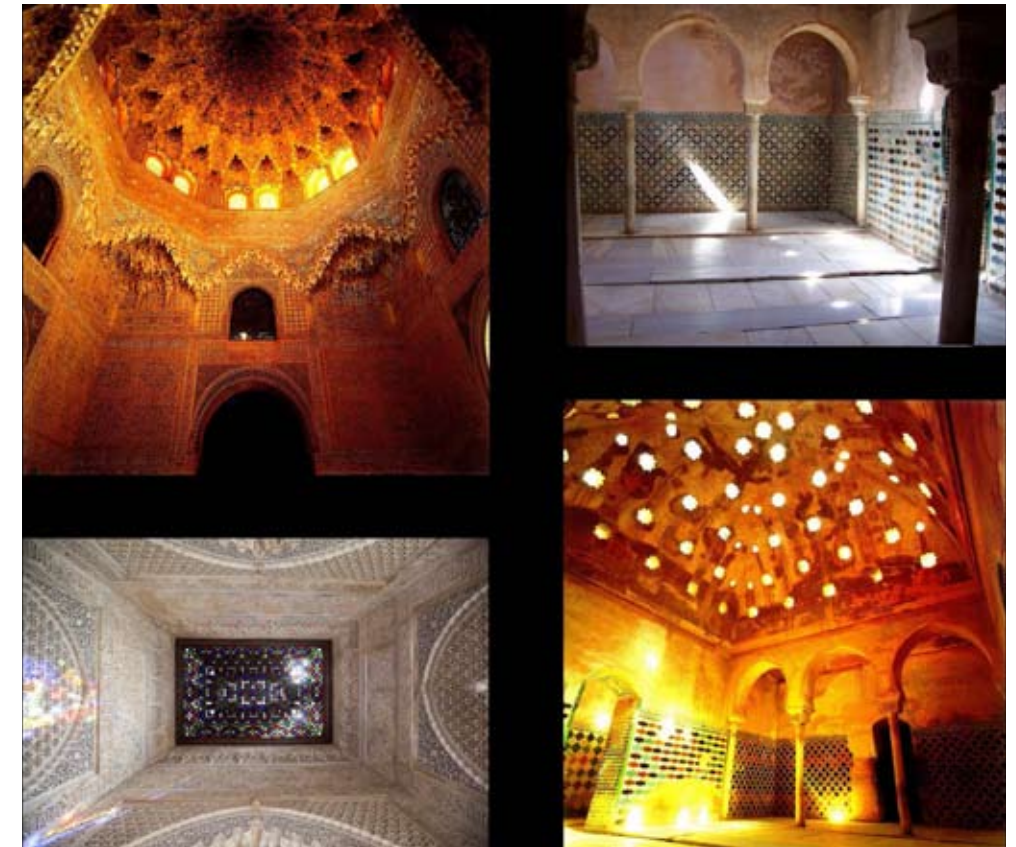


Image 6.3. Controlled inner illumination in different spaces in the Alhambra (photographs 1 and 4 from Miguel Rodríguez Moreno, in: Orihuela Uzal, 1996: 99, 109).

and heat capacity, which also provides protection against the hot summers. In short and cold winters little braziers and heaters would be used. Residual heat of the private baths usually situated near the main north chamber also could be used for heating some rooms. In addition strategies were developed to receive a higher incidence of sunlight and the entrance of natural light in

some rooms that could be used in winter.

6.1. Natural Refrigeration

The natural refrigeration in *Nasrid* architecture is achieved in two different ways (Jiménez Alcalá, 1999: 13-29, Jiménez Alcalá, 2011): Preventing heat from penetrating the interior of the building, by means of direct

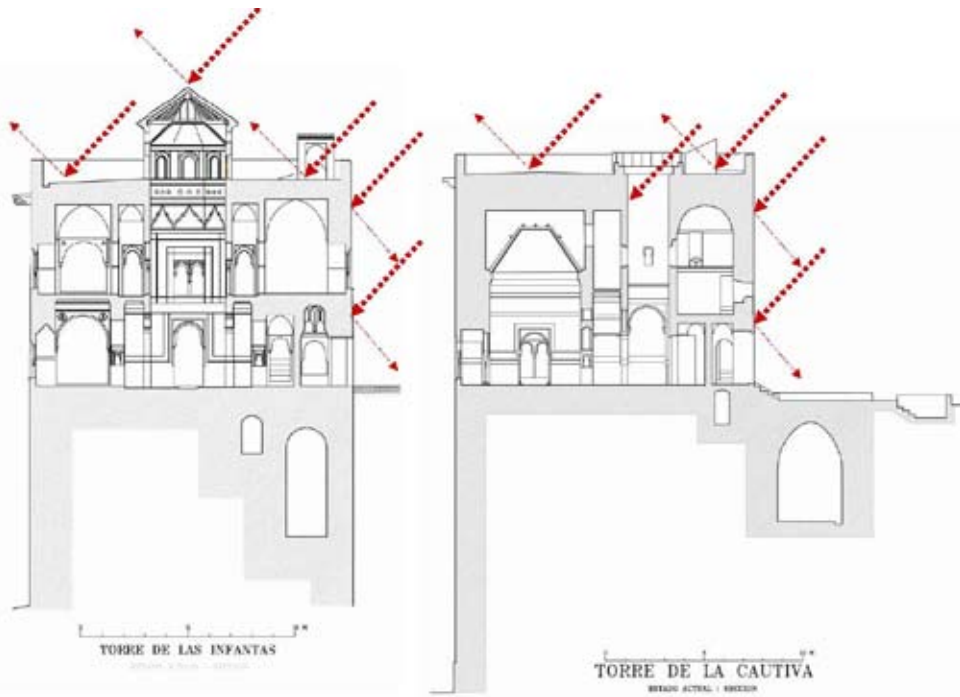


Image 6.4. Passive protection against the sun in thick walls buildings (after maps from Orihuela Uzal, 1996: 131 and 141).



Image 6.5. Ventilation effect in the Las Infantas and La Cautiva towers-houses in the Alhambra (after maps from Orihuela Uzal, 1996: 131 and 141).

protection against the sun (Image 6.4), and eliminating excess temperature from the different areas to be cooled using a series of combined physical mechanisms (ventilation, radiation and evaporation) (Image 6.5).

6.1.A. Direct Methods of Active Refrigeration (Heat Prevention)

6.1.A.1. Control of Spaces and Natural Light

Strong solar radiation is the

main reason for internal heat in the buildings developed in the geographic area where Islamic culture spread, with medium to high temperatures and a predominance of clear days (Image 6.6). *Al-Andalus* was no exception, and the buildings that were developed provided protection from the rays of the sun primarily by preventing its direct entrance. The inner illumination is always soft, because the openings for sunlight are generally small and precisely located. As

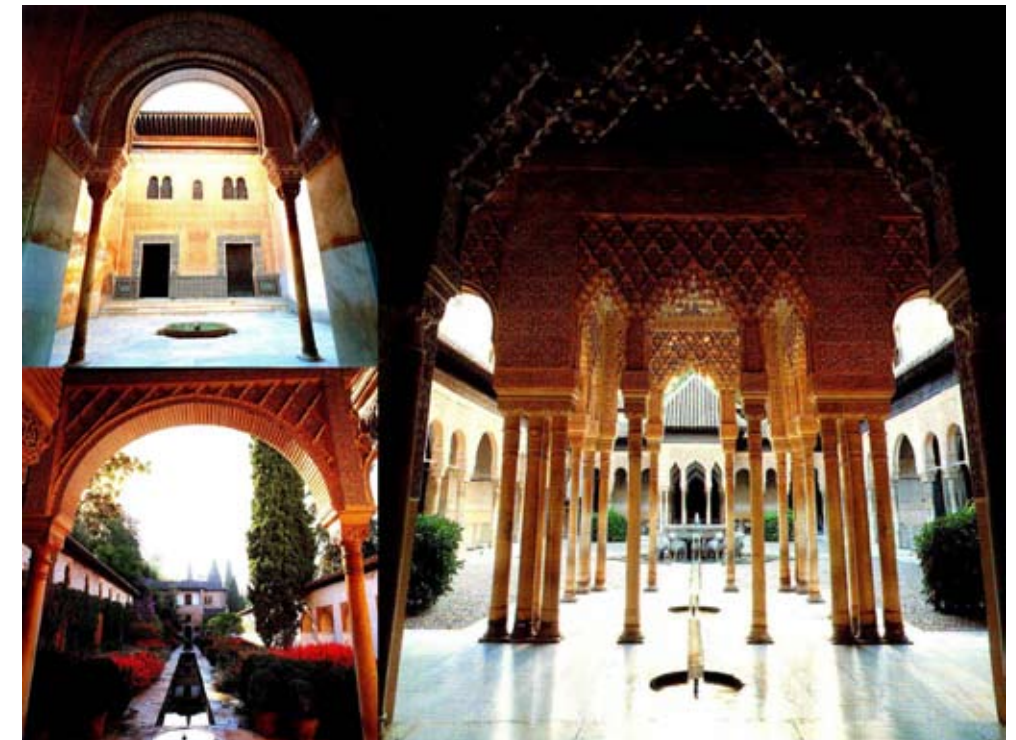


Image 6.6. Controlled inner illumination in different porticoes in the Alhambra palaces (photographs from Miguel Rodríguez Moreno, in: Orihuela Uzal, 1996: 82, 106 and 205).

a consequence, the influx of sunlight and hot air is reduced to the minimum, achieving a desired level of illumination and ventilation. The larger openings, such as entrance arches, are protected with wooden doors, deep porticoes, and pronounced eaves, always present in the sunniest wings of the patios. These porticoes are often made up of arcades with *sebka* designs through which there is a gradual adjustment of light from the floor to the upper parts of the walls.

The inner illumination is usually indirect, and rarely comes from solar penetration (Image 6.7). The windows always have lattice work that filters and moderates the influx of light. The ones located at ground level are placed in small bay windows that deflect direct light. Such is the case in the Hall of Ambassadors of the Palace of Comares, the Mirador of Lindaraja of the Palace of Lions or the Mirador of the Room of the Kings of the Generalife. In the larger openings to the patios, the

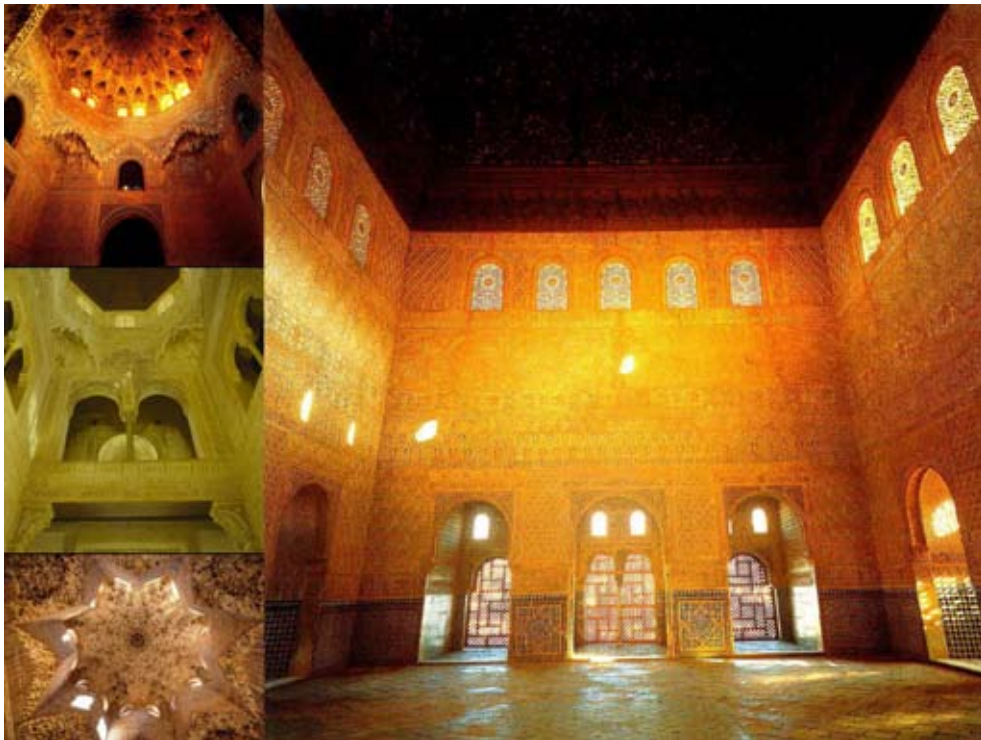


Image 6.7. Controlled inner illumination in different spaces in the Alhambra palaces (photographs from Miguel Rodríguez Moreno, in: Orihuela Uzal, 1996: 90, 109 and 142).

presence of porticoes graduates the ingress of light, which is reflected off successive surfaces until it reaches the interior. In the process of transition between the outside and the interior there is a graduation in luminescence.

The most common practice was to confine this indirect illumination to the higher part of the rooms, which made the light from top to bottom somewhat hazy, giving a suggestive atmosphere to the interiors. The light from above

bathed the surface of the walls and showed up their astonishing decoration, made up of inscriptions, mosaics, elaborate wood work, ceramic skirting and polychrome *muqarnas*. In this way a sensation of splendor was obtained in buildings made for the most part with poor materials.

In addition, Islamic architecture “plays” with the light and the visual effects that it produces (Image 6.8) not only in decoration but also when it penetrates between



Image 6.8. Reflecting water surfaces in the Alhambra (photographs from Miguel Rodríguez Moreno, in: Orihuela Uzal, 1996: 87 and 203).

the trees of the gardens and when it “plays” with the water: reflecting the architecture in the ponds or shining in the water of the fountains and irrigation channels.

In the Alijares Palace (Alhambra’s Hill, 14th century) the control of the natural light was made by means of a profusion of vitreous panels in the upper part of the *qubbas* (Image 6.9). The text of Ibn Asim makes this clear when indicating that the way it was built prevented

sunlight from entering the *qubbas* directly through its doors, because these did not have other openings in the ground floor. As in other cases, in the central pool of this palace could be seen the effects of the reflection from the *qubbas* and columnated galleries.

6.1.A.2. Reflecting Surfaces

Another direct way to avoid the excessive heating of the buildings was obtained through

Image 6.9. Vitreous panels in the upper part of the *qubbas* of the Abencerrajes and Dos Hermanas in Lions Palace (above, photographs from Miguel Rodríguez Moreno, Orihuela Uzal, 1996: 105 and 109) and in the Alijares Palace (hypothesis) (below) (García-Pulido).

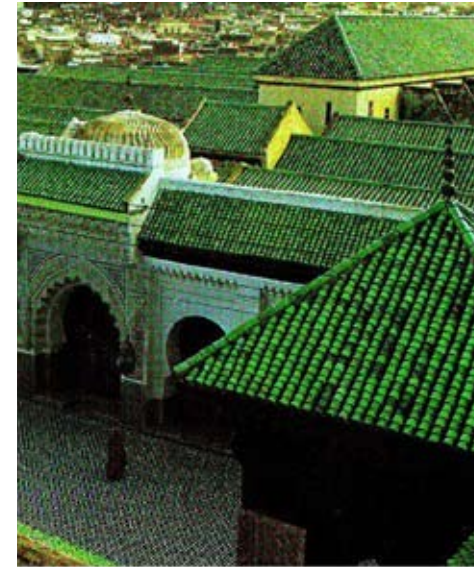
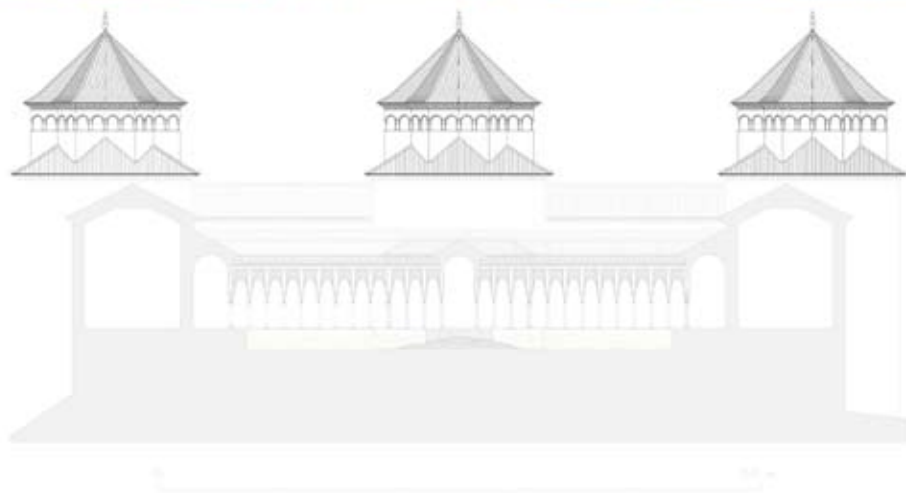


Image 6.10. (Above) Vitreous roofing tiles in mosque Karaouiyine in Fez (912-933), with two similar pavilions to those of the Palace of the Lions built in 1613. (Below) Vitreous roofing tiles represented in the historical image from 16th century of the Alijares Palace (Sala de las Ballatas del Escorial).

the reflection of a part of the solar rays from the outer surfaces of the building, which would thus absorb less solar energy (Image 6.10).

White or clear surfaces were created using a raw material that abounds in the limestone regions of the Iberian Peninsula, lime. So rooted has this tradition become that in many towns of Andalusia the houses are still painted with lime each spring, their overall white color standing out.

The use of ceramic in skirting as well as in roofs was another system that assisted the reflection of solar rays. This fact is demonstrated in the magnificent tiled domes of the formal *qubbas* in the eastern Islamic cities such as Samarcand, Soltanieh or Isfahan. In the case of the Alhambra, the present-day roofs are covered with non-vitreous tiles, except for those of the ridge tiling, where often the colors are alternated green and white. Nevertheless during the *Nasrid* period all the roofing material could have been made up of vitreous roofing tiles, as is indicated by numerous examples found in archaeological remains. In addition this feature can be observed in diverse constructions of North Africa which received a great number of refugees from *al-Andalus* after the conquest of Granada by the Christians in 1492 and the definitive expulsion of the last *Moriscos* in 1609. Among

them is the mosque Karaouiyyine de Fez (912-933), with two pavilions similar to those of the Palace of the Lions built in 1613.

The example of Alijares Palace is one of the most significant in this regard. It stood on top of a red hill, highlighted by its bright white color, as is referred to in the epigraphic poems than were composed for the palace itself by the poet Ibn Zamrak. In the center of its biaxial courtyard was placed a *Nasrid* style elongated pool. The floor of the palace was covered entirely with white marble, and the skirting on the walls had multicolored tiles. Judging from the remains found in archeological digs, it could also have had ceramic tiles on the roof.

6.1.A.3. North-South Orientation

“Any space that is oriented from north to south sharpens our experience of a day. Both main walls are lighted, but at different hours. Every morning, light from the east will cast a shadow that moves quickly down the opposite wall and across the floor. Every afternoon, light from the west will cast a shadow that crosses the floor and

climbs the opposing wall. To experience the whole cycle takes from before sunrise until after sundown.

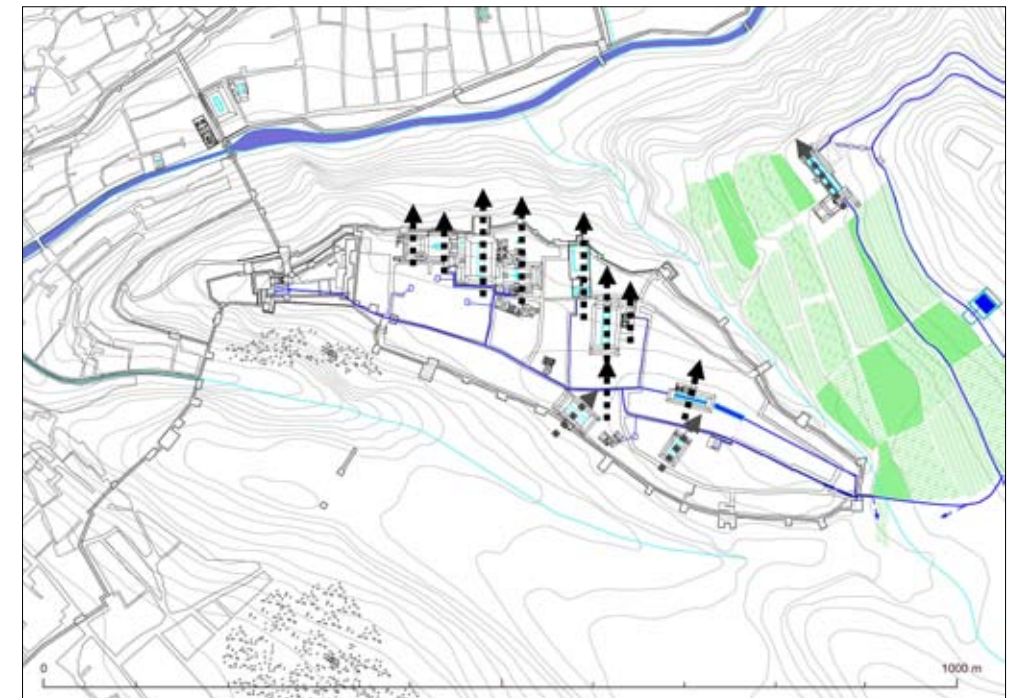
Where east-west and north-south spaces pierce each other, we can experience both time scales. The common volume intensifies both a seasonal and a daily cycle. It combines them, laying one over the other. The result is a crossing in space that proportions time. Its celebration has often lifted architecture out of the region of fact into the realm of art” (Knowles, 1998).

The most important way of solar control is choosing an appropriate direction for the building and how the doors and windows are positioned with relation to the sun (Image 6.11). Islamic domestic and civil constructions are not conditioned by a precise direction toward Mecca, as happens in religious buildings. Therefore, whenever the urban or topographic conditions allowed it, *Nasrid* houses and palaces tried to establish themselves along a north-south axis. The main rooms and *qubbas* are placed on the north side with its interior façade facing south, which in the

Mediterranean latitudes provides easy protection from the sun, because of the different inclination of the solar rays. In summer they have so high an angle of incidence that they do not penetrate the interior of the building. In winter the inclination is much smaller, and the solar rays penetrate with more depth, helping to warm up the rooms. In contrast, the east and west façades are least favored by the low inclination of the sun in the summer mornings and afternoons, when the incidence of sun rays is at its highest. For

the latitude in which the *Nasrid* kingdom developed (around 40° north), the façades facing the east and west receive two and a half times more solar radiation in summer than in winter, whereas the southern façade receives in summer two times less radiation than in winter because it remains in a shaded area (Jiménez Alcalá, 1999: 26, Olgyay, 1957). In the central hours of a summer’s day, the highest solar radiation would be received by the roofs in a north-south oriented building. So the heat of the day would

Image 6.11. North-South orientation in the main palaces of the Alhambra (Orihuela Uzal and García-Pulido).



affect the higher air masses in the main chambers and winter rooms on the second floor, but would hardly have any effect on those for summer use, set mainly on the ground floors. A façade facing south with a protective portico brings together therefore optimal conditions of natural protection against sun in summer and maximum penetration of solar energy in winter. During a typical day in summer, the inclination of solar rays is so high and the general direction such that there is no solar penetration into the most important rooms. At noon, the sun illuminates the patio but without affecting the interiors. In the morning and afternoon, however, the sun penetrates through the hollows of the west and east wings respectively.

In the 14th century, the agronomist Ibn Luyûn wrote a treatise giving some advice about the ideal agricultural estate for the *Nasrid* kingdom areas (Image 6.12). Regarding orientation he says:

“A house amidst gardens should be located in a dominant position for reasons of defence and vigilance. It should face the midday sun, the entrance at one side,

and a well or a pond should be placed on the upper part; or instead of a well, better a canal running underneath the shade... All the great fruit trees must stand in the north part, in order to protect the rest of the property from the wind” (Eguaras, 1988).

In Granada there are many cases that exemplify the preference of *Nasrid* architecture for the north-south orientation, where the most important rooms were located in the north wing of the patio, with the main façade facing the south (Image 6.13). However, east and west walls do not have openings to the patio, or only restricted ones for ventilation and light, due to their unsuitable orientation. Among them we have:

ALHAMBRA: Palace of Comares, Palace of the Lions, Palace of the Generalife, *qubba* of the Palace of the ex-convent of San Francisco, Palaces of the High and Low Partal, Palace of the Secano.

MEDINA OF GRANADA: Dār al-Horra, House of the Chapiz, House of Zafra, Houses in Oro and Covertizo of Santa Inés streets.

MALAGA: Palace of Quarters of Granada of the Fortress of



Image 6.12. View of the palace of the Generalife nowadays from its orchards.

Malaga. The adjacent marine breeze, whose temperature is pleasant and constant, can be used to cool the day long.

The exceptions are those constructions in which the urban layout determined their direction, or those in which other factors, such as territorial control, took precedence over bioclimatic ones. An example of this is the *qubba* of Cuarto Real of Santo Domingo, whose tower is based in one of the walls of the city of Granada, looking outwards in a southeasterly direction.

The most singular case is the Alijares Palace, in which an orientation deliberately different from the four cardinal points was sought. Although its orientation is the best that suits the orography of the hill on which it was built,

there was enough space to accommodate the architectonic complex with the four cardinal points. Its orientation is similar to the mosques of Granada, so that the southeastern *qubba*, called *al-quibliya*, faced toward Mecca. Perhaps this fact could have been in relation to the religious practices of the Sufix that took place in this palace.

On May 21 at 36° north latitude (southern Spain), an elongated courtyard with orientation north-south displays the following features (Reynolds, 2002: 9-13):

At 9 AM the floor is in shadow. The sun just grazes the short north face, leaving its arcade in shadow. But sun illuminates almost all the long west face and its arcade. At noon about 4/5 of the courtyard floor is in sun, and the short north

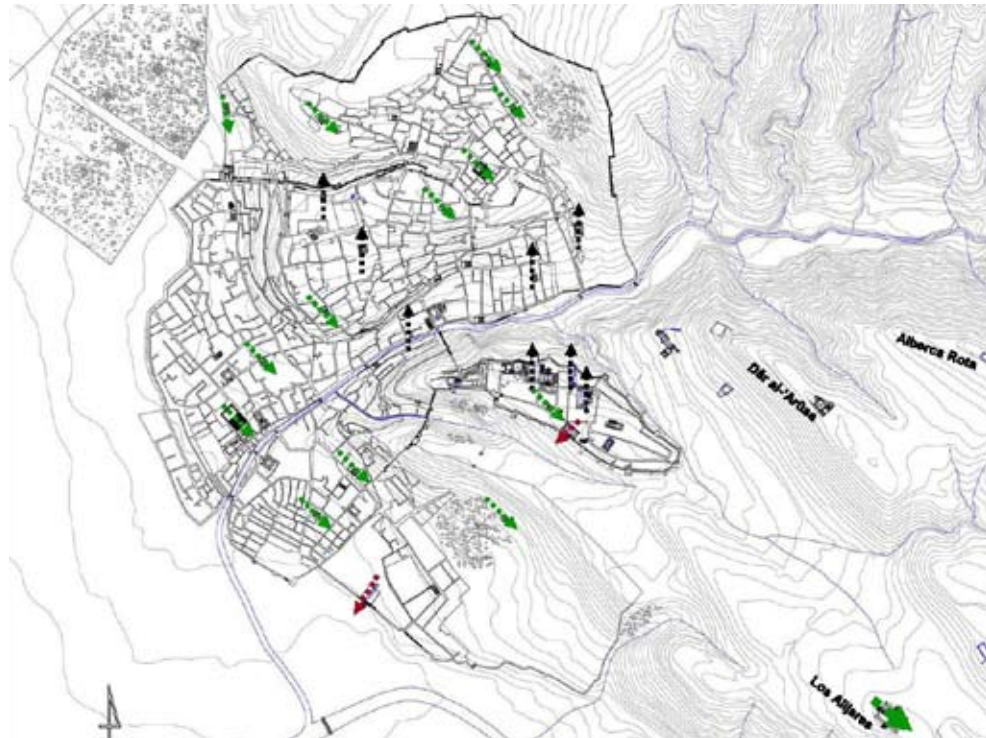


Image 6.13. North-South orientation in the main palaces and houses in *Nasrid Granada* (the green arrow belongs to the buildings with religious purposes) (Orihuela Uzal and García-Pulido).

face is fully illuminated. But the high sun angle leaves much of the north face's arcade in shadow. At 4 PM the floor is again in shadow. The sun, due west, just grazes the short north and south faces, leaving their arcades in shadow. The sun illuminates about half the long east façade and its arcade.

On December 21, at 9 AM almost all is in shadow. The sun only illuminates the top of the short north face and strikes the long west face, just above the top of

the arches. At noon the courtyard floor is in shadow, except for the very back of the short north arcade. The sun only grazes the top of the long east and west faces. The short north face is almost fully illuminated, with deep penetration into the arcade. At 2 PM the sun penetrates more than halfway down the wall in the northeast corner of the courtyard, with a small patch of sun in that corner of both the arcades of the north and east faces. All else is in shadow.

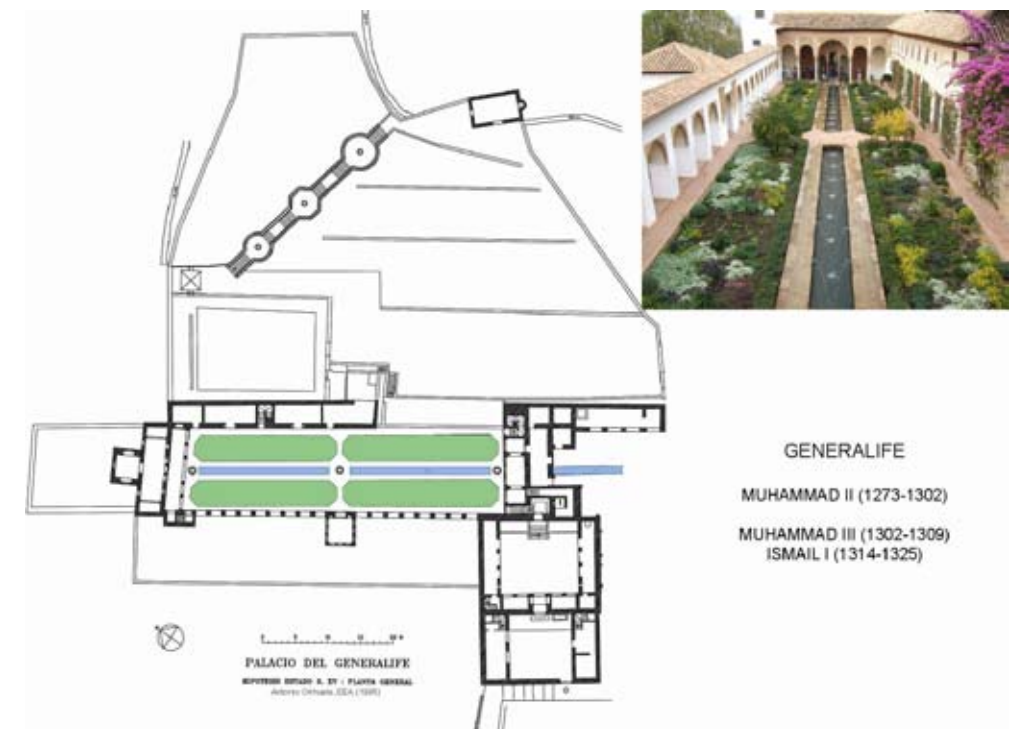
6.1.A.4. Microclimate Provided by Courtyards

The patio within a house lights and ventilates the rooms of the house, collects the rainwater and, at the same time, regulates the climate in a natural way. It is the place around which the Muslim domestic world revolved. It worked as a thermoregulator for the rest of the house, accumulating pockets of nocturnal fresh air, which provided insulation against the heat of the day (Jiménez Alcalá, 1999: 18). The vegetation inside the patio

provided shade, gentle light and increased humidity (Image 6.14).

Appropriate layout and orientation of patios prevented solar penetration, at least in the middle hours of the day and during the warmest season. The volume of the patio was the determining factor in respect to its thermal efficiency. A space higher than it was wide was advisable to maintain more shade. But in varied climates, with cold winters, large patios maximize the entrance of sun in winter and keep it shaded

Image 6.14. The Generalife (Orihuela Uzal, 1996: 109-220).



in summer. Porticoes, pergolas, awnings, plants and shrubs act as a filter against the intense light and reduce the contrast between the brightness of the outside and the cool shade of the interior.

The temperature and humidity were controlled and mitigated by water and vegetation in the patios. Both are sources of evaporative cooling. Cooling by radiation was crucial as well, being the usual form of natural refrigeration in continental climates. The high inertia or thermal capacity of the walls surrounding the patios kept off and slowed down internal heating. At night, the patio cooled off easily through ventilation and the remission of long wave caloric energy. With these processes, the patio was insulated from the heat and dryness outside during the day and, after sunset, it was able to eliminate the stored heat.

In the Alijares Palace the eastern tradition of a biaxial garden was revived, particularly as the Palace of the Lions had once lacked a garden (Image 6.15). This type of patio works well in palaces of huge dimensions like the Alijares one, and would have provided humidity and shade for the porticoes in the Palace of the

Lions. Only two palaces in the Alhambra (Generalife and the palace in the ex-Convent of San Francisco) had had a cruciform garden, and both come from the end of the 13th century. The presence of an elongated pool in the center of the courtyard would contribute to the creation of temperature differences and resulting airflows through water evaporation.

6.1.A.5. Spatial Dispositions around the Courtyard. The Sequence of Patio, Portico, and Qubba or Tower

In addition to the environmental character that the patio and the garden have, the way in which the rooms were placed around it influences the correct distribution of the microclimate generated in the house.

The addition of a *qubba*² to the

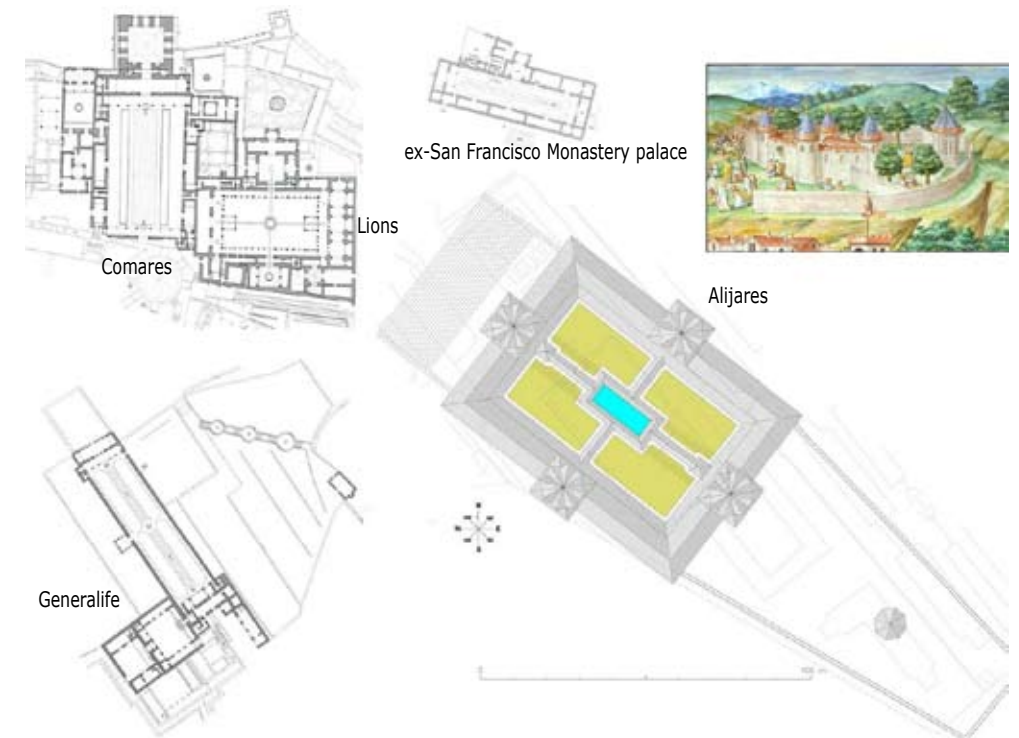
² Although the word *qubba* is normally referred to a dome, a tomb, or a ritual space off the central hall (Ragette, 2003: 289), in *al-Andalus* this word is also related to a thick-walled regal tower, generally with a quadrangular shape and covered internally with a dome that is not usually visible from the outside.

main axis (Image 6.16), generally located in the north wing, improves the bioclimatic conditions of a palace (Jiménez Alcalá, 2000: 229-230, Jiménez Alcalá, 2011). It has perimetral windows in its high part to illuminate and ventilate, while in the lower part they are usually closed to the outside, although not to the garden. If they have any opening to the street it is small, designed to provide a strategic and precise view.

Between the *qubba* and the

patio is placed an intermediate or transition space. The waiting room to the *qubba* usually is a portico (Image 6.17), which works as thermal shock absorber for the patio. In the Palace of Comares, due to its dual use as a royal residence and throne hall, the sequence is even more complex, because the Sala de la Barca (the Room of the Boat) (Image 6.18), placed between the tower and the portico, is the private apartment of the king. Another singular case is the Patio of the

Image 6.15. Orientation and size of the palaces of Comares, Lions, ex-San Francisco Monastery, Generalife (Orihuela Uzal, 1996), and Alijares (García-Pulido).



Lions, because in its smaller axis are arranged *qubbas*: the Room of the Two Sisters and the Room of the Abencerrajes. And the most complex of all would be the Alijares Palace with its 4 *qubbas*, porticoes, and covered walkways (Image 6.19).

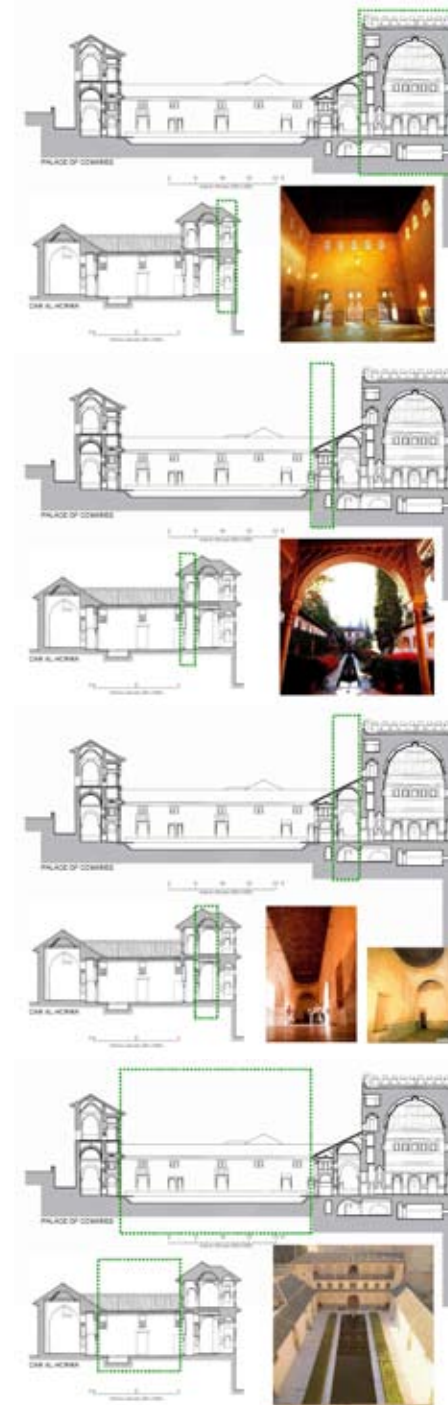
The bioclimatic properties attributed to the sequence consist essentially in the climatic interaction among patio, portico, and *qubba* or tower. The three elements complement each other in order to improve the thermal conditions of the ensemble. The patio generates a cooler microclimate than the exterior. Nocturnal air is accumulated at the base of the patio because of its higher density and its deep form keeps large surfaces in the shade. Furthermore, vegetation and water, always present in patios, refrigerate by means of their evaporative cooling potential. On the other hand, due to its shape, volume, and fenestration, the tower's internal air is stratified and, as a consequence, the warmer air is easily evacuated through the upper windows. The tower also acts, moreover, as a ventilation tower for the rest of the building. It sweeps the internal heat from other rooms by means

of the airflow established between patio and tower. Finally, a portico is normally inserted between patio and chamber. It shelters the hall entrance and protects its external walls from the sun, thus performing as transitional space or a thermal buffer of both microclimates.

Some experiments have shown that the climatic conditions of *qubbas* remain very stable throughout the day and within the considered margins of comfort (Jiménez Alcalá, 1999: 27, Willmert, 2011: 162-167). In the middle hours of the day the ventilation is counterproductive, whereas for the rest of the time its effect is beneficial.

Temperatures and humidities are much attenuated in the interior of the *qubbas*, and more in the patio than in the outside. In the hours of scorching heat, the difference with the interior can reach 12°C and with a proportional increase of relative humidity of more than 15%. Furthermore the delay produced in the hours of maximum heat between inside and outside is two hours. In *Nasrid* times the main rooms would be closed by a heavy wooden door and perhaps with tapestry in the inside, which

Images 6.16-6.19. The sequence patio, portico, tower or *qubba* in the Palace of Comares and Dār al-Horra (after maps from Orihuela Uzal, 1996: 97-226).



would isolate and prevent the entrance of large quantities of hot air. The lattice windows located over the main gates (between 2 and 5) would work then, and would allow the cross ventilation in the high parts of the *qubbas*. This retardation is produced by the radiating effect of the wide walls that surround these *qubbas*.

Due to the orientation of the Alijares Palace (Image 6.20), the four *qubbas* were built with the same dimensions and degree of importance, even though the northwest worked as the principal one. By its biaxial characteristics, the palace established the sequence patio, portico, and *qubba* in four directions, in which the longitudinal ones could have had pavilions similar to those of the Palace of the Lions. Therefore the sequence would have been amplified having itself a central pool in the patio, covered walkway flanked by vegetation, pavilion, portico, and *qubba*.

6.1.B. Indirect Methods of Passive Refrigeration (Heat Dissipation)

In *Nasrid* architecture, the natural mechanisms of ventilation, evaporation, and radiation (Jiménez Alcalá, 1999: 16-18), each one effective separately, are combined to obtain better results (Image 6.21).

6.1.B.1. Ventilation

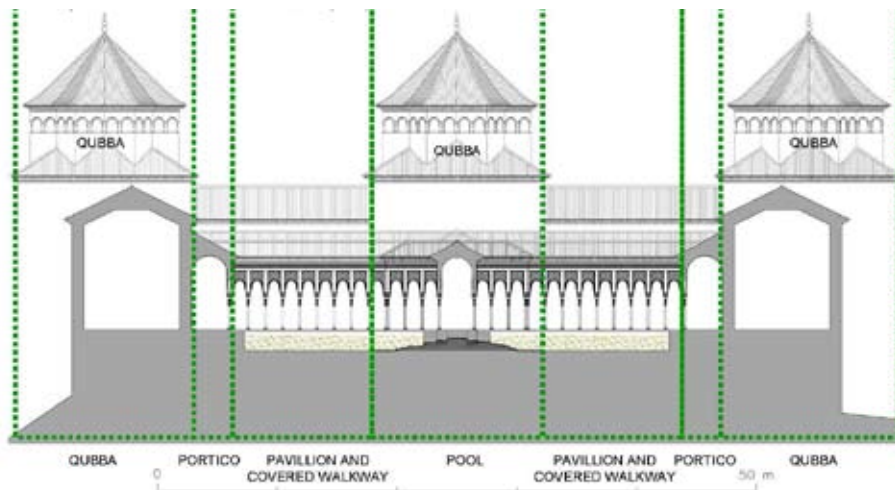
Ventilation provides cooling because of the air movement that evacuates and drags the heat that is generated in inner spaces, as well as the heat from the surface of the human body. The benefits produced by the ventilation are perceived in two ways:

First, the movement of the air causes the loss of heat by convection. Normally, the temperature of the air is cooler than the human skin, and reduces the thermal sensation in the body.

Second, air close to the skin is saturated. The contact with the air flow causes the absorption of part of the humidity of the skin, which produces a refreshing effect.

The effective ventilation of a room depends on the distribution and shape of the windows, not only with regards to their size, but also strategic placement with the aim of obtaining suitable cross-ventilation. The evacuation of the hot air is improved if there

Image 6.20. The sequence patio, portico, and *qubba* in the Alijares Palace (García-Pulido).



are more and larger openings in the high part, because the hot air is lighter and tends to be accumulated in this zone.

In climates with dry and warm summers as in the case of Granada, from mid-morning to the setting of the sun, the temperature of the outer air tends to be too hot and higher than the inside one. The buildings, therefore, usually remain closed since it is not possible to make use of the refrigerant potential of the air. When the interior is closed to the external air, the wide walls provide some cooling. These isolate the outer atmosphere and store the heat during the central hours of the day, which maintains the interiors cool. During the

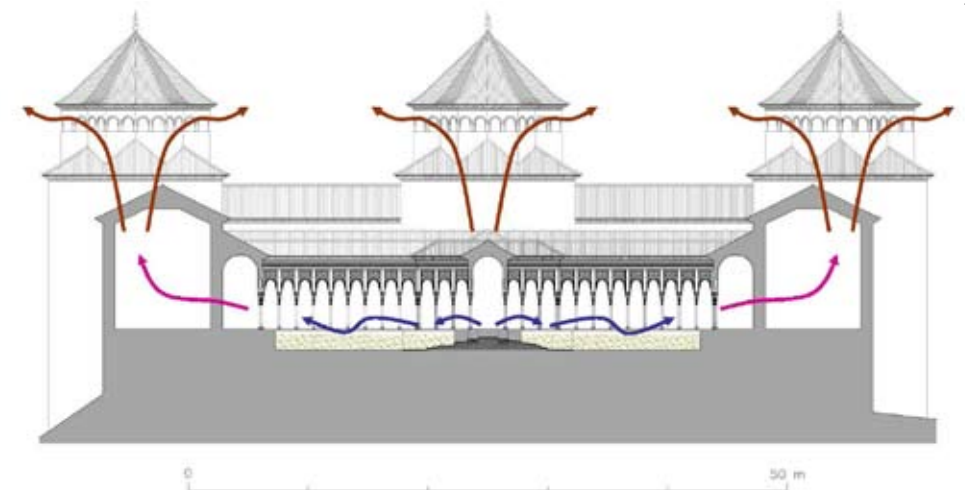
night, the walls and roofs begin to radiate the accumulated heat. As a consequence, the structure of the building will dissipate with facility the warm air with nocturnal ventilation.

In *Nasrid* buildings there are three different means to ventilate rooms in a natural way (Jiménez Alcalá, 1999: 17):

The *Stack effect*, which is originated by a difference of air density and pressure between the heavier cold air and lighter warm inside a space (Image 6.22).

The *Venturi effect*, which occurs when a rapid air circulation provokes a lowering of pressure. This takes place in areas with

Image 6.21. Ventilation cooling system in the Alijares Palace during day (hypothesis) (García-Pulido).



cross ventilation, where the draft induces air from other areas, thus creating air convection (Image 6.23).

An the *Wind-Driven effect*, which happens when external wind is induced into the interior and the pressure difference created is used to take out internal heat. Wind can be drawn internally by strategically located openings (Image 6.24).

6.1.B.2. Radiation

Thermal radiation is the energy that a surface emits in electromagnetic waveform based on its temperature. If two elements with different temperatures are opposed, a radiant flux from hottest to coldest is established with the effect of balancing both temperatures (Jiménez Alcalá, 1999: 17-18).

The surfaces exposed to solar radiation, such as tile roofs, grounds and walls, store the solar energy received during the day (Image 6.25). During the night, and due to the thermal radiation phenomenon, they begin cooling, radiating the heat stored toward the celestial vault (Image 6.26). This radiation also takes place

from the walls toward the rooms, warming up the air, and it is preferable if there a suitable nocturnal ventilation to evacuate it.

The radiative cooling works with effectiveness, with the help of materials of a great resistance and heat capacity, which delay the heating until the nocturnal dissipation. This property to alter the heat flow between the outer and inner atmosphere is known as thermal inertia. Therefore, the radiative cooling depends on the thermal conductivity of the material and the thickness of the walls. When the temperature of the outer air rises and the wall is exposed to the solar radiation, the temperature of its external face rises, which, if it is higher than that of the internal face, causes a heat flow towards the interior. The speed of the flow will depend on the width and the thermal inertia of the material.

6.1.B.3. Evaporation and Evapotranspiration

The physical principle of this kind of cooling is based on water evaporation that takes place when vapor pressure on the water is higher than the adjacent air one

Image 6.22. *Stack effect* in the sequence Patio-Portico-Qubba in the Palace of Comares (after map from Orihuela Uzal, 1996: 97).

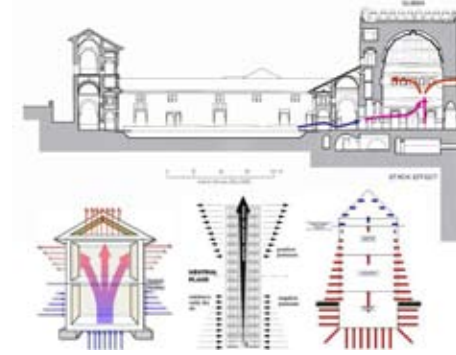


Image 6.23. *Venturi effect* in the sequence Patio-Portico-Qubba in the Palace of Comares.

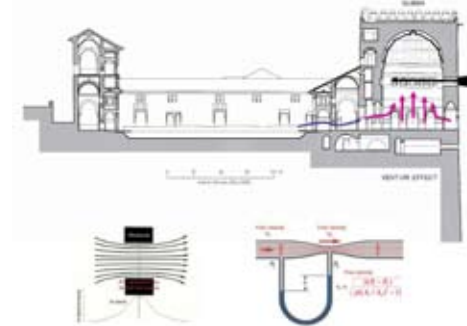
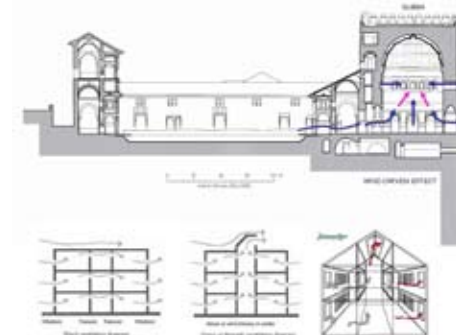


Image 6.24. *Wind-Driven effect* in the sequence Patio-Portico-Qubba in the Palace of Comares.



(Jiménez Alcalá, 1999: 17). In this case, the water in liquid state is transformed into vapor. The required energy (latent heat) is taken from the air, which is cooled, at the same time that its humidity increases. The evaporative power of the air will be higher in dry and warm climates, and under specific conditions, the capacity of cooling by evaporation can be so high that it is possible to reduce the temperature by 14° C.

Evaporative cooling is a resource used from remote times. The water can be stored in different ways, but in general the more exposed it is to the air, the greater the advantages that will be obtained. We can find it from fountains, jets, ponds, and also obtained from the vegetation whose leaves always contain superficial humidity (which result in evapotranspiration). The cooling due to vegetation can reach 8° C below the surrounding areas (Argirion and Santamouris, 1993). The vegetation not only improves the thermal and humidity conditions of the air that crosses it, it also has other environmental benefits, like filtering the air flow, cleaning it of dust and contamination, softening the noise, and mainly providing shade.

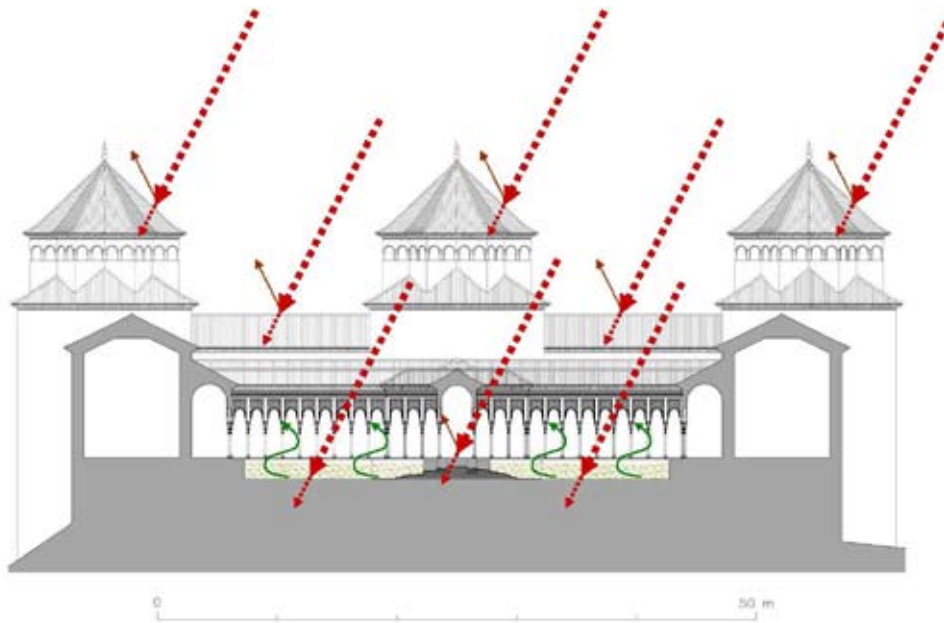


Image 6.25. Sketch of sunrays' reflection and evapotranspiration in the Aljares Palace during the day (García-Pulido).

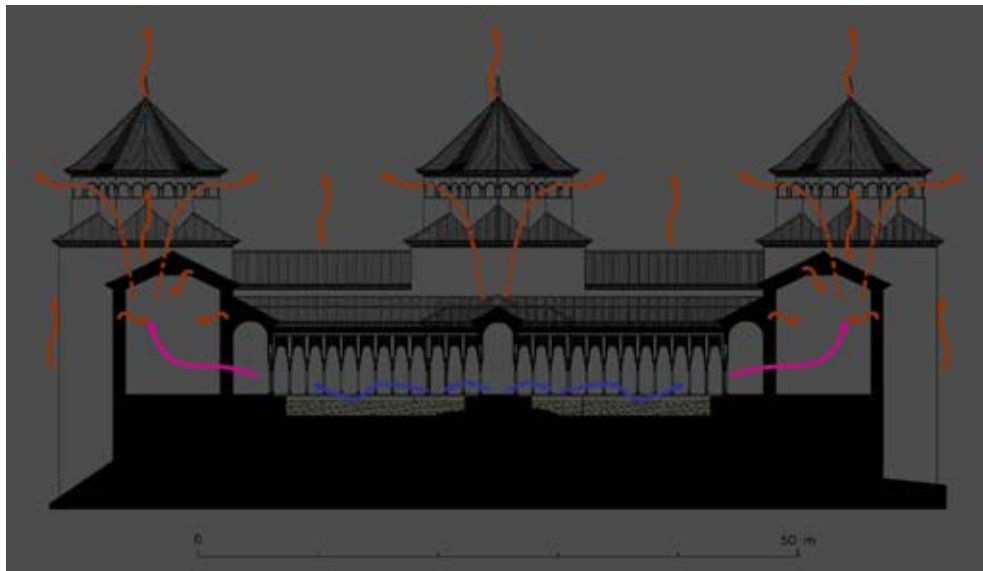


Image 6.26. Sketch of radiative cooling in the Aljares Palace during the night (García-Pulido).

All the interpretations with regards to the Islamic garden in general, and the *Nasrid* one in particular, agree in the understanding that it is like a representation of the Paradise on Earth, used for rest and pleasure. In addition, the garden placed in the patios of the houses and palaces benefit them environmentally. The orchards and gardens in *al-Andalus* became a poetic genre of literature.

Water is always present in the gardens, where it assumes a transcendental meaning. The disposition of the gardens came be determined by the systems of irrigation and water distribution. The location of palaces and gardens, and even cities, depended mainly on the water available, making possible the agricultural development of the city of Granada (Image 6.27), and



also the development and support of the Alhambra on a dry hill.

7. BIOCLIMATIC DEVICES IN OTHER ISLAMIC REGIONS WITH COMPARABLE CLIMATOLOGY TO THE SOUTHEAST IBERIAN PENINSULA

7.1 The North West of Maghreb

“... le Maroc de la fin du XV^{ème} siècle avait recueilli en grand nombre les exilés andalous après la prise de Grenade (1492), main-d'oeuvre appréciable d'une rare qualité, à n'en pas douter, techniciens, artistes et savants qui auraient dû insuffler une énergie nouvelle comme cela avait été le cas sous les Mérinides ; il es vrai que Fès avait, pour sa part, reçu depuis longtemps la leçon des Nasrides au point que la capitale pouvait apparaître une cité andalouse transplantée en territoire maghrébin, par ailleurs, les émigrés d'Espagne s'installèrent surtout dans les villes du Nord du Maroc...” (Le Tourneau, 1949: 73).

Image 6.27. Agricultural states of the city of Granada in *Nasrid* times (García-Pulido, 2011: 261-311; García-Pulido, 2013: Fig. 101).

The northwest of Maghreb has great environmental variations, due to contrasting coastal and inland zones, as well as altitudes from zero to 4000 meters. Two distinct population groups, Arabs and Berbers, share these territories, merging diverse design contributions. The expansion of Islam beyond Egypt around 670 AD meant the Arabs controlled the north coast of Africa, including Tunisia, Algeria, and Morocco, and *al-Andalus* in the Iberian Peninsula.

The Atlantic coast of Morocco is washed by the cool Canaries Current that keeps summers notably cool for the latitude, the highest recorded temperatures being only just over 40°C. Inland, summers are hot and dry with bright sunshine, but near the coast low cloud and fog are not infrequent. In winter the prevailing winds are westerly, bringing rain from the Atlantic and often heavy snow over the High Atlas Mountains of the interior.

Courtyard houses were part of North African settlements well before the arrival of Islam in the region. The Berbers had their houses organized around courtyards and this is still the case

in various mountain villages (Image 7.1), as one-story farmhouses in the Middle Atlas, where the influence of the Roman *domus* is still visible. The courtyard is surrounded with posts as columns as a remainder of the *impluvium*. The most important rooms are in the corners and not in the center of the main sides. Courtyard houses were also widespread in North African Roman settlements such as Volubilis in Morocco; Carthage and El Djem in Tunisia; and Timgad, Djemila and others in Algeria (Sibley, 2006: 49).

Another tradition found in Morocco is the *Ksarhouses* (Image 7.2), built between the wall and the counter wall of a fortified city.

Image 7.1. Middle Atlas courtyard 100 m² farmhouse with indirect entry, patio with six post and large skylight surrounded by four rooms (Laoust, 1932 and Ragette, 2003: 10)

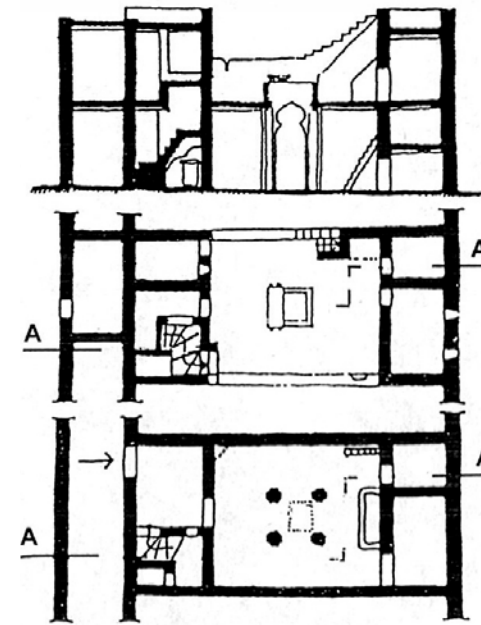
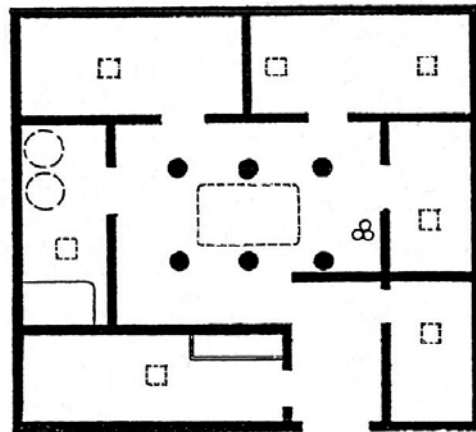


Image 7.2. Ouled Limane, a double-loaded patio Ksarhouse with a large entry, a twisted stairway and few and small rooms (Adam, 1951 and Ragette, 2003: 10)

They usually had a wide covered courtyard with a quadrangular skylight in the center, allowing the circulation of air and controlling the entrance of light.

The *Tighremts'* (Image 7.3) shape is also conditioned by their defensive features, so they have a massif shape, being usually arranged between four corner towers. Sometimes they had a skylight as in the *Ksarhouse*, mainly in the upper stories, and in the lower ones a corridor take the place of the central courtyard,

usually situated behind the front door (Ragette, 2003: 108).

Clusters of courtyard houses are the main component of the urban fabric of major Islamic cities in the Maghreb. The dominant formal characteristics of the courtyard house in these cities are the absolute centrality of the courtyard with its perfect geometric form and ingenious adaptation to the irregular contour of the plot. The plan of the house may vary in detail, but its basic characteristics are kept and the hierarchy of the spaces and the general organization of the houses are very similar. However, the size and character of the houses and their courtyards in these cities do vary. The bent entrance is followed by a transitional space creating a buffer zone. The courtyard is deep and the stairs and service areas are located in the corners of the house. The reception room is the most decorated room and is usually near the house entrance.

The early courtyard houses of Fustat (Egypt) during the 8th and 9th century show regular central square patios, with symmetric and T-shaped reception rooms (Image 7.4). This early house form probably influenced the Maghrebi

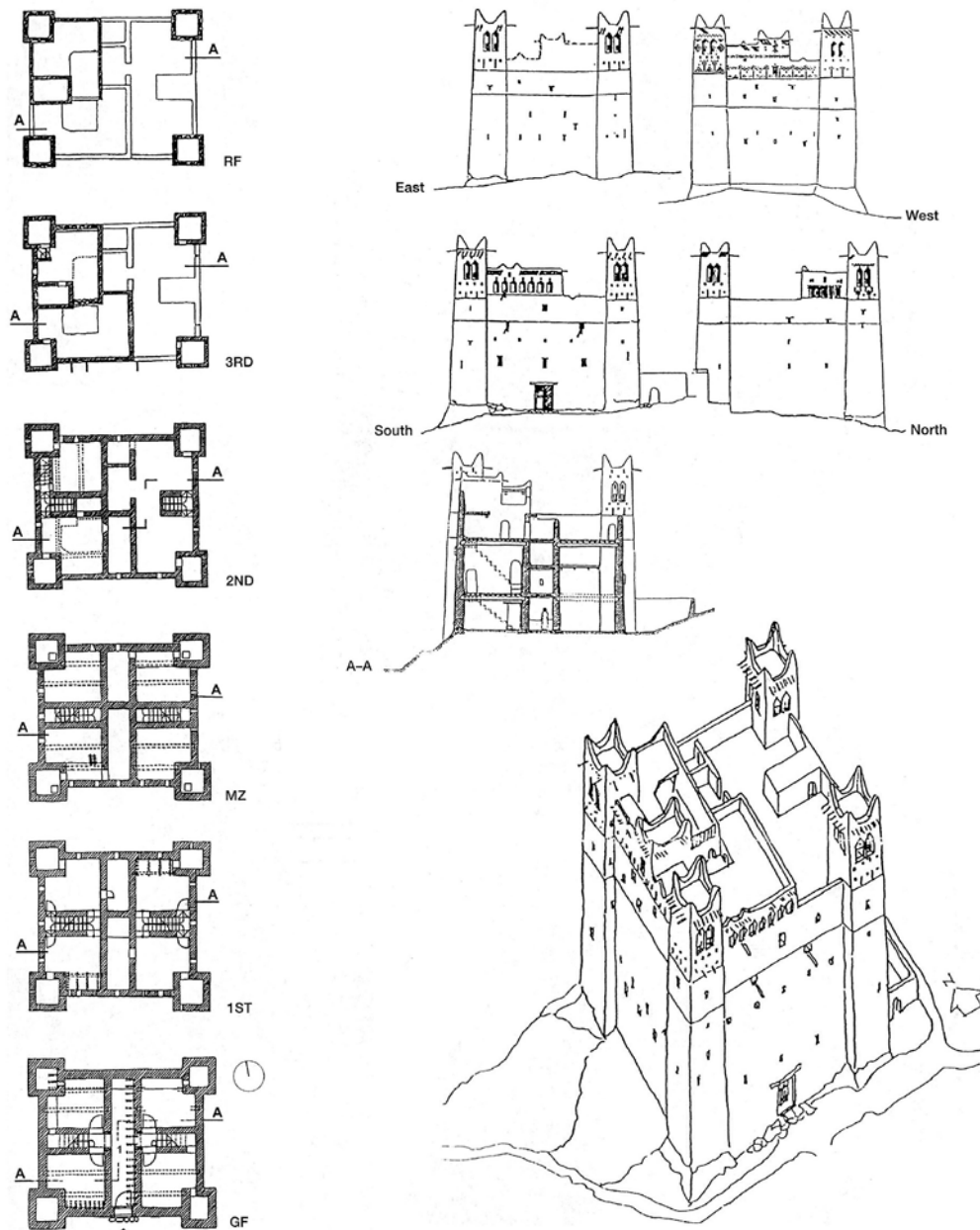


Image 7.3. Ait Hamid, symmetrical *Tighremt* of 24 m height and 30x30 m², with a central corridor instead of a patio and two opposite stairs defining four corner spaces with its corner tower attached (Adam, 1951 and Ragette, 2003: 112).

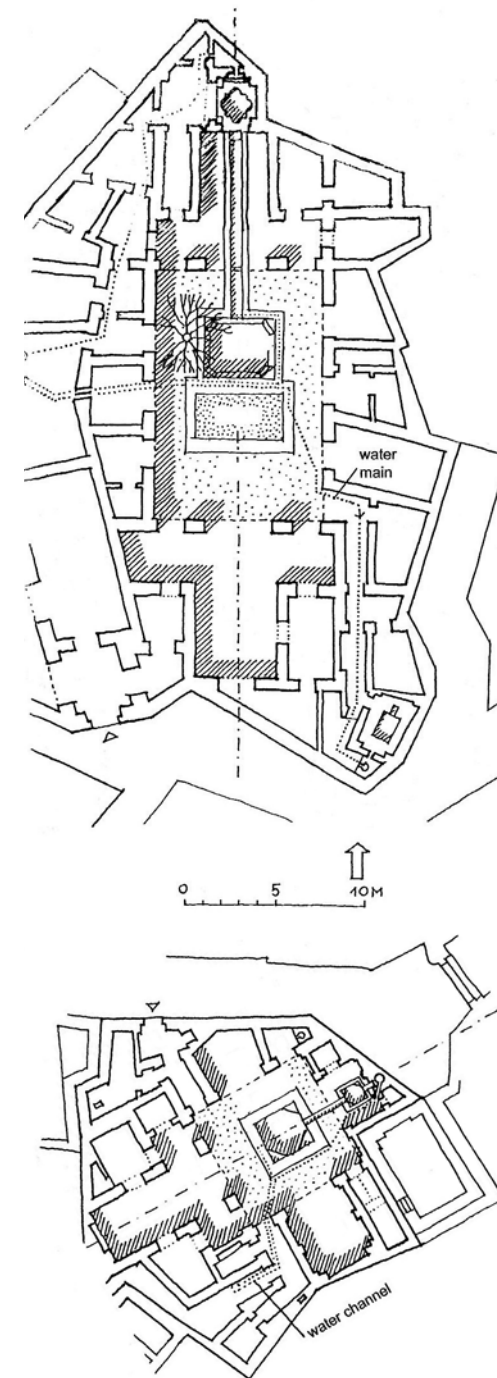


Image 7.4. Ninth century houses in Fustat with regular rectangular courtyards, peristyles and iwans arranged in an irregular plot and the axis emphasized by fountains and water channels (Gabriel, Albert and Bahyat, 1928 and Ragette, 2003: 143).

courtyard house organization. The T-shaped rooms are evident in the courtyard houses of Tunis and Algiers and could be reminiscent of the early Fustat courtyard houses, but they disappear in the western regions Morocco and *al-Andalus* (Sibley, 2006: 49-62).

7.1.1. The Courtyard House in the Medinas of North Maghreb

Townhouses are found in the cities of the littoral and the lowlands northwest of the mountains. They subscribe to the introverted courtyard scheme with a simple gallery or complete peristyle and often elaborate courtyard elevations (Ragette, 2003: 113).

In the *medina* of Fez large residential quarters are still lived in today. They present entire clusters of modest courtyard houses as well as fine examples belonging to wealthy families.

The work of Jacques Revault's team on the courtyard houses of

Fez (Revault et al., 1985) reveal that the typology has remained with little changes from the *Merimid* period (14th-15th centuries) until the 19th century and that the organisational principles are the same whether for a large palace or a modest courtyard house. Size and level of decorations are the only indicators of differences in wealth among courtyard houses' owners and occupants.

Courtyard houses in Fez are characterized by their verticality and their deep patios. The oldest type of houses present either continuous columns up to the projecting roof or two

layers of columns interrupted by a first floor gallery (Image 7.5). Most of them are built on rectangular plots with a width to height ratio varying between 1.5 and 2 (Sibley, 2006: 49-62). The houses are usually three-story structures with intermediate levels. The rooms are organised along the longitudinal axis which frequently presents a north-south orientation, as is the case of Dār Lahlou (Raguette, 2003: 115), Dār Mzelja, Dār Lazreq, Dār Lazreq (Derb el-Médersa), Dār Zouiten, Dār Demāna (Image 7.6) (Revault, 1985: I), Dār Ben Šeqrūn or Dār Bou Helāl (Revault, 1985: II). They share diverse composite

Image 7.5. Ground floors of Dār Sqolli (left) and Dār Demāna in Fez (14th-15th centuries) (right) in Fez (17th-18th centuries) (Revault, 1985: II, 86 and 196).

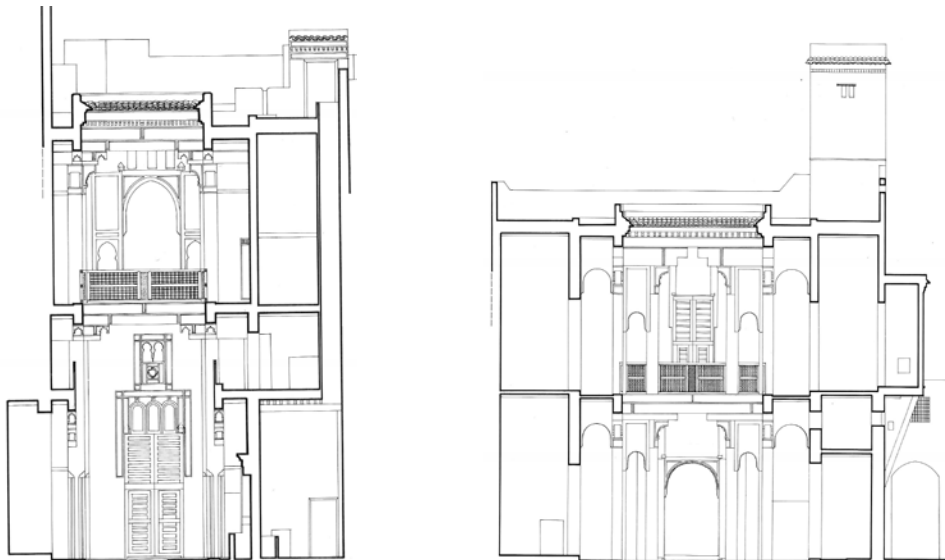
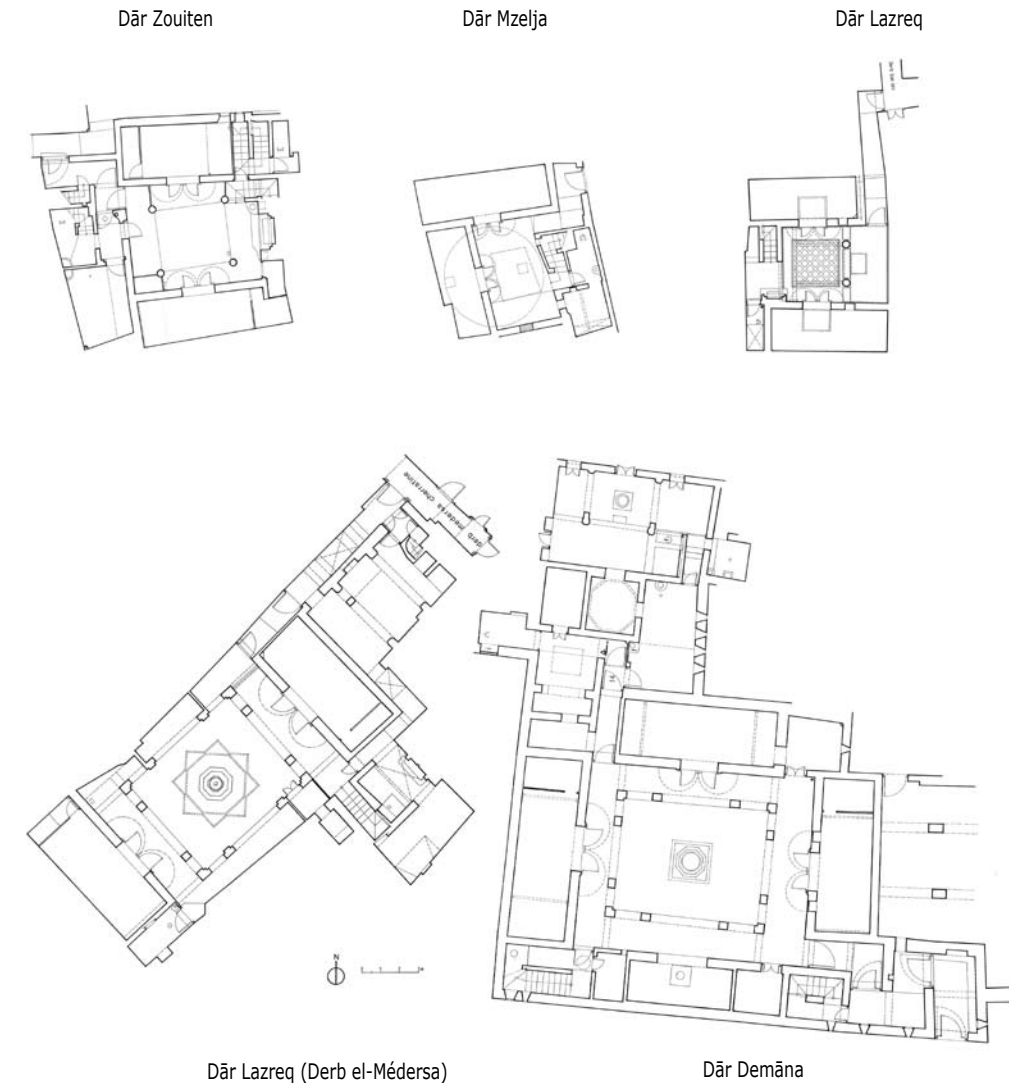


Image 7.6. Ground floors of Dār Mzelja, Dār Lazreq, Dār Lazreq (Derb el-Médersa), Dār Zouiten, Dār Demāna in Fez (14th-15th centuries) (Revault, 1985: I, 113, 127, 137, 167 and 185).



principles with the Andalusian *Nasrid* and *Morisco* houses. The main rooms face each other and have large double-winged rooms and porticoes. The staircases are placed in strategic corners of the building without being exposed to the courtyard. In most regions of *al-Andalus*, the roof were sloped and covered with tiles, due to the pluviosity. But in the Maghreb normally one staircase leads to the roof terrace.

Adjacent houses are occasionally joined to form one large dwelling. In that case one of the houses becomes the private domain of the family. The other spaces are organized around a light well and provide a private living area for a married son or for guests.

The courtyard is the focus of outdoor living space and various domestic activities such as food preparation, laundry, and children's play. As in other courtyard houses of the Muslim world, there is a bent circulation space which prevents any visual intrusion from the alleyways into the private central space of the house.

These features have been conserved in the dwellings from

the *Alawite* period (17th-18th centuries). In these houses the chimney of the kitchen, placed in the ground floor, is in some cases associated to the main north room, as happened in Dār Bou Helāl and also in Dār Sqolli (Image 7.7). Thus, in winter the fireplace and chimney can contribute to heat the main rooms of each story, and this should be an adaptation in the traditional Magrebine dwelling because of the colder conditions of these centuries. In *al-Andalus*, the chimney might have been used in the massive and compact dwellings without patios of mountain regions such as the Alpujarra in the Sierra Nevada, but never in the townhouses.

The traditional urban courtyard house in the *Kasbah* of Algiers also consists of a ground floor and two-story structure organized around a deep square courtyard (Image 7.8). The individual rooms are long and shallow and occupy a full side of the square patio, normally surrounded by three-arched galleries on the four sides, providing a covered circulation and a transitional space between the rooms and the open courtyard. As in other cases the patio is accessed through a small bent space acting as a buffer zone

between the exterior and the interior of the house.

Secondary spaces such as the kitchen, toilets, stairs, and storage are relegated to the irregular-shaped corners of the house, and are usually located on the first floor. The courtyard and the roof space, where activities take place, provide completely different spatial experiences that complement each other. The shaded, enclosed, and highly private courtyard space is in complete contrast with that of the roof terraces.

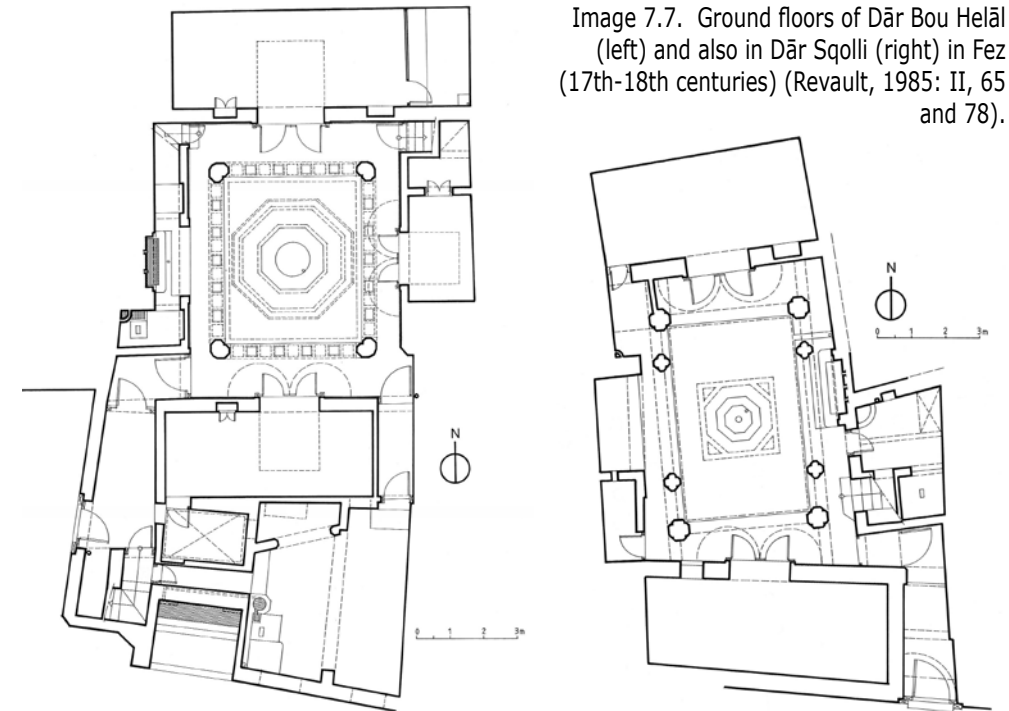


Image 7.7. Ground floors of Dār Bou Helāl (left) and also in Dār Sqolli (right) in Fez (17th-18th centuries) (Revault, 1985: II, 65 and 78).

Other specific features can be found in the corbelled overhanging volumes of the external façades, allowing discreet side views from the house to the public streets.

The courtyards in Tunis's *medina* are rather wide and open (Image 7.9). The spatial characteristics of these houses remained unchanged from the 16th to the 19th century (Revault, 1967), and their architecture contains features present in early al-Fustat residences in Egypt (Sibley, 2006: 49-62). The courtyard is

surrounded by a series of long and narrow rectangular T-shaped rooms, where the central area opens onto the courtyard and balances the two lateral sitting rooms, where the central area bays. Each room constitutes an

Image 7.8. Constantine (Algeria), house Ben Sharif, plans and oblique cut-away view. The roofs drained most of the rainy water into the quadrangular courtyard and on to the cistern (*L'Habitat traditionnel dans le Pays Musulman autour de la Méditerranée. Variation et Mutations*, 1991 and Ragette, 2003: 124).

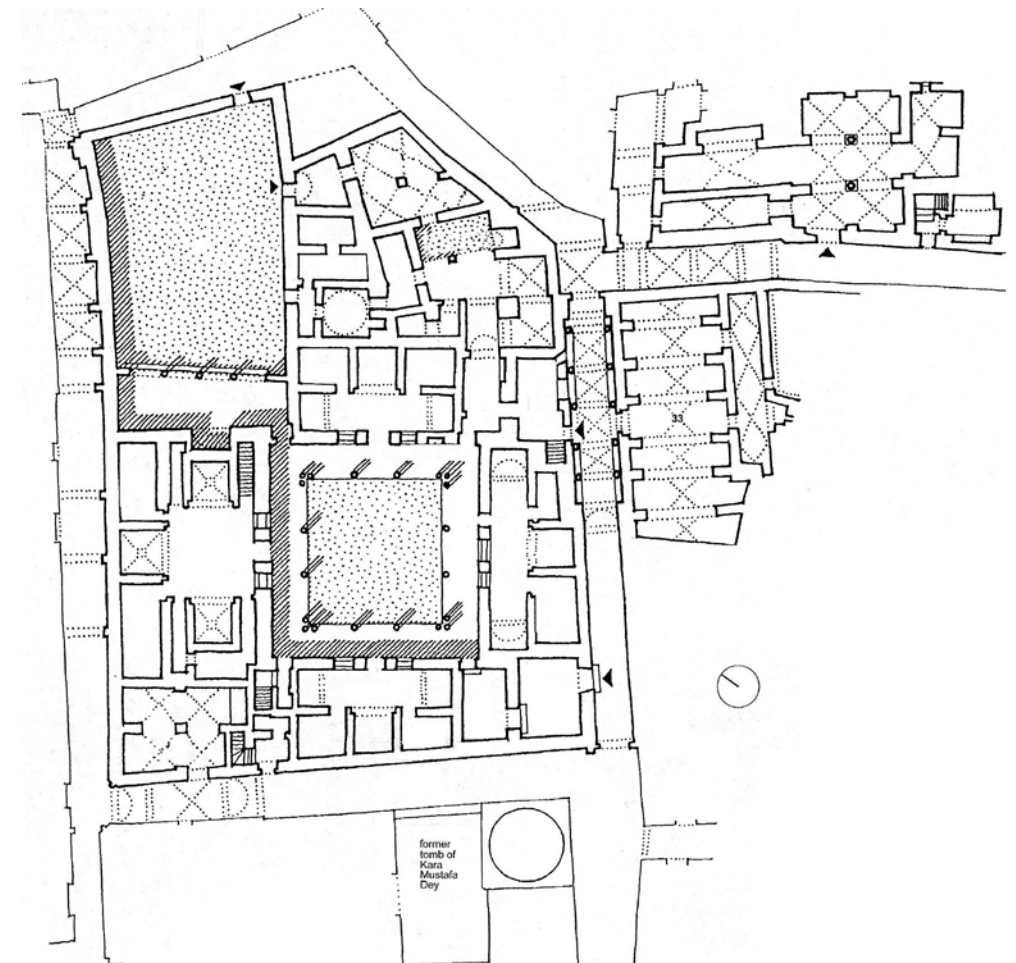
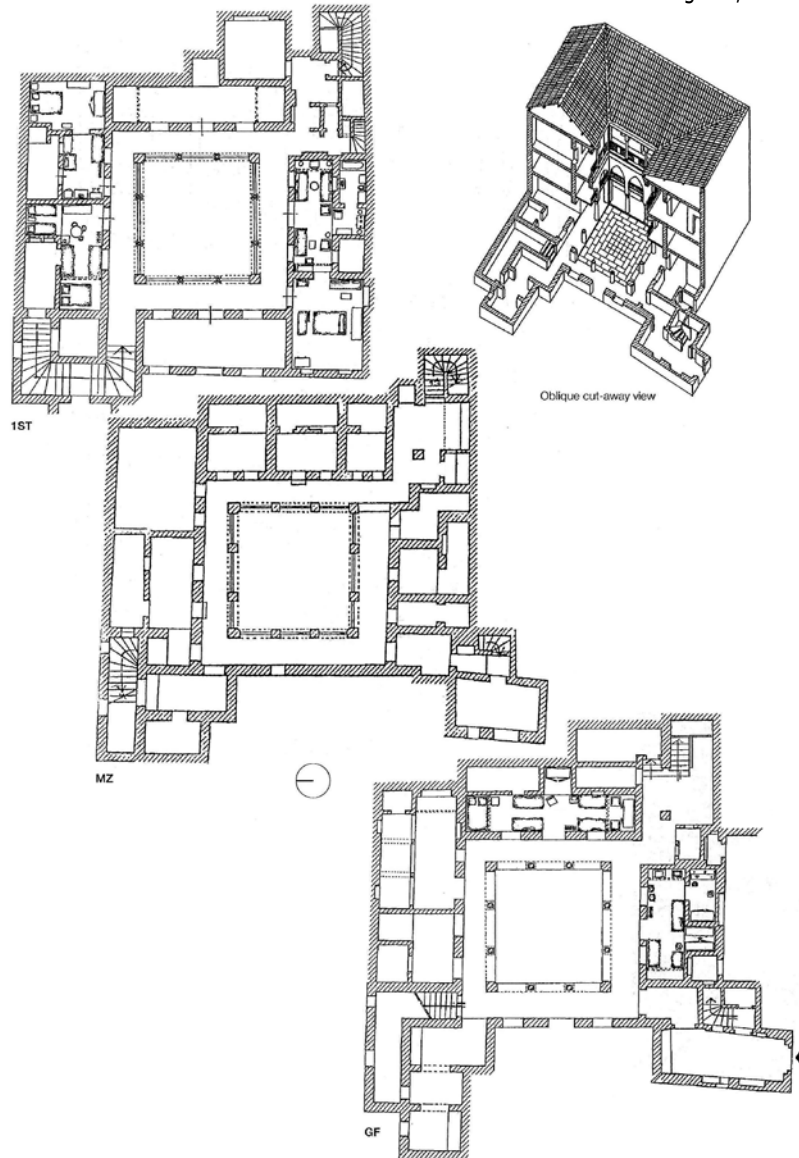


Image 7.9. Tunis, house Husayn, surrounded by lanes on all sides and a large service wing attached garden that complements the courtyard (Revault, 1967/71 and Ragette, 2003: 132).

autonomous spatial unit with a multipurpose uses and has its own entrance and courtyard façade.

Among the differences between these courtyard townhouses of the main cities from Maghreb and the latest Islamic houses of *al-Andalus* are the following:

First, the houses of Fez, the *Kasbah* of Algiers and Tunis usually have four porticoes and the shape of the patio tends to be quadrangular with eaves at the same height, remembering the *impluvium* of the Roman *domus*. The *Nasrid* archetype house has a rectangular courtyard and

normally two porticoes. The whole patio surrounded by porticoes is well documented in *Morisco* houses from the 16th century.

Second, the townhouses of northwestern Maghreb usually have three stories. Compared to the houses in Tunis, the courtyard houses of Fez and Algiers have higher vertical proportions. This can be explained by the steep slopes than form the site and the need to increase density as the city expanded in the 16th century, after the arrival of *al-Andalus* refugees. As a result, in these aspects they are also more similar to the houses developed by the *Morisco* society in the southeast of the Iberian Peninsula.

7.2 The Anatolian Peninsula

The different typologies of Turkish houses derive from the merging of different civilizations and construction traditions, established in the course of the Turkish movement westwards through Anatolia and large areas of the Balkans. The flexibility and versatility of the principal room, known as *sofa* in the Turkish culture, was combined with the

permanent solutions adapted to the particular conditions of indigenous cultures long settled in Anatolia, thus creating new architectural forms and a diversity of regional house types. Whatever the materials used, the fundamental principles of spatial organization remained similar, even if this gave rise to differences in the form of the houses. Wood was used in the mountain slopes facing the Black, Marmara, Aegean, and Mediterranean seas; stone in eastern and southeastern Anatolia and adobe and stone in the hinterland and central areas of this peninsula. In central Turkey, where both wood and stone were in short supply, adobe was the main building material, providing extremely good insulation. Adobe walls were reinforced at intervals by wooden posts, and were plastered with thin mud every year, they were not sufficiently strong unless reinforced with the timber. Timber was by far the most widely used material, at three quarters of the total only in the Anatolian Peninsula (Sözen, 2001: 62). In the absence of timber, stone was preferred if available, leaving wood for doors, window frames, ceilings, floors, and bay windows. In these buildings bay windows

were created by extending the heavy wooden beams beyond the stone walls on which they rested.

The Anatolian Peninsula protrudes into the large inland area and is essentially subject to the Mediterranean climate. The climatic conditions, orography, and particularly panoramic considerations were the main factors in the layout of a settlement and the arrangement of main spaces of the dwellings. Over the centuries the Turkish house has been designed principally to provide protection from extreme weather conditions while taking advantage of those aspects that make life easier and more pleasant. The effects of climate on spatial organization differ from region to region. Adverse climatic aspects of the northern regions are low temperatures, wind, and high precipitation, while in the south they are high temperatures and lack of wind (Sözen, 2001: 56).

However, the importance of views and magnificent natural scenery in some Anatolian regions influences the orientation of a house even when this might entail exposure to wind or other

undesirable weather conditions. The most important living spaces, like the *sofa* and *köşk* room, turn to face the view despite climatic disadvantages, and usually face northwards, even if the north and northwest directions are the most exposed to winds and precipitation (Sözen, 2001: 69-70). If the site does not offer significantly better views in any one direction, then climatic considerations are given priority. On flat terrain the most appropriate direction for rooms to face is east or south. But in northern Turkey the west is also considered desirable. This was so for houses all over Turkey, so other measures are taken to counteract the drawbacks, such as the widespread use of fireplaces and chimney breasts as an important feature of the main rooms (Image 7.10). This element is not common in Islamic architecture, and it is only present in northern and mountain regions, and also as an influence of European culture.

Vernacular architecture in Turkey is also shaped by social and cultural structure. Domestic life patterns, relations between family members, and local solutions to the provision of diverse needs

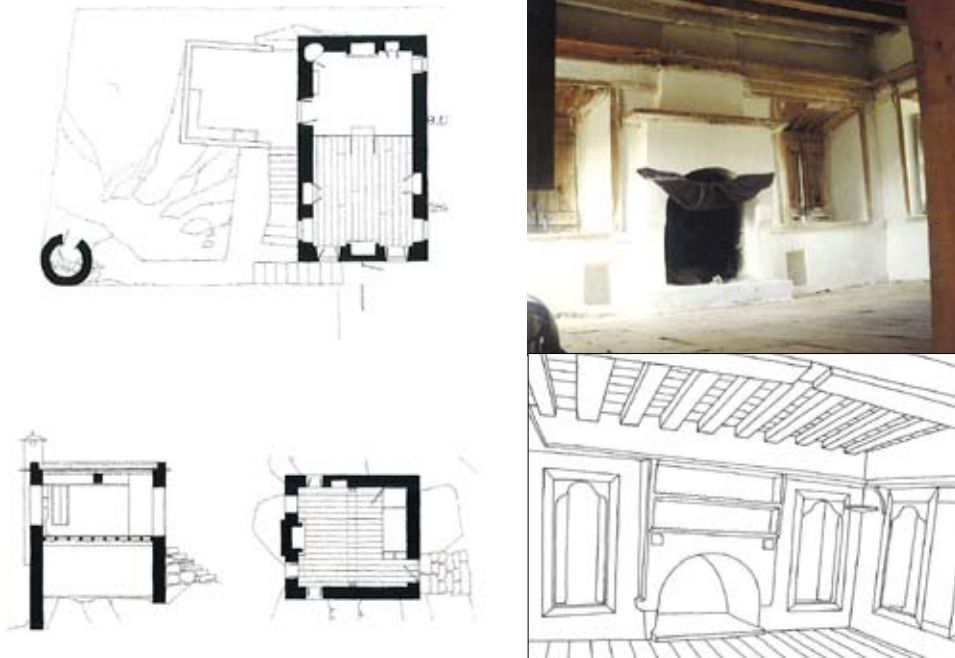
all affect spatial composition (Sözen, 2001: 65). So relations of production, climate, topography and other factors give rise to differences in spatial organization of vernacular architecture. These are accentuated and given further diversity by people's spiritual beliefs, so that even where climatic conditions, vegetation, and building materials are identical, these beliefs give rise to differences in conception that are reflected in architecture.

There are four main climates in the Anatolian Peninsula, and each one has contributed to different pattern in housing traditions:

7.2.1. Mediterranean Continental Climate

In the Bodrum Peninsula in southwest Anatolia, the settlements and buildings give evidence of sensitivity toward the Mediterranean continental climate. They are found mainly

Image 7.10. (Above) Akçaalan house in Anatolian's Bodrum Peninsula; rectangular room with two fireplaces. (Down) Hanay house in Southwest Anatolia (Milas, Muğla) (Aran, 2000: 138 and 140).



on hillsides facing east, south, or southwest. Buildings consist of single cubical structures with whitewashed thick masonry walls. Window openings are small and few in number; they are equipped with shutters that open inwards. Roofs are covered with earth, and buildings in hillside settlements are provided with a terrace in front of the main door. Sometimes, a front trellis with climbing vines

screens the terrace against intense sunlight (Aran, 2000: 96). During summers, the terrace, equipped with a fireplace at one corner, turns into an open kitchen and together with the window shutters that are kept closed, ensures a cooler and shaded indoor environment (Image 7.11).

7.2.2. Mediterranean Marine Climate

Under the Mediterranean marine climate of southwest Anatolia, buildings are oriented toward cooler winds but protection from solar radiation is also important.

Settlements consist of widely spaced clusters of discretely placed single-mass buildings. Living spaces of one or two rooms are built on top of ground floor granaries and usually have

Image 7.11. Terrace in front of the main door with front trellis in Southwest Anatolia (Aran, 2000: 100-101, 148 and 156).



surrounding trees. Each room is equipped with vertically elongated narrow windows, normally four, placed in pairs just across from each other. Building masses are covered with tiled roofs sloped on four sides. Two-story buildings are positioned at the northern side of the courtyard and get more and more elevated above the ground as they come closer to the hillside. Rooms placed on top of granaries, to the rear of widely eaved deep loggias facing courtyards, gain protection from solar radiation and profit from summer breezes. Nevertheless, the need to limit surfaces exposed to intense summer solar radiation is still noticeable in the whitewashed cubical houses protected by high courtyards walls, and also in the closely clusters of courtyards.

In other regions, houses with multi-story structures are erected on stone walls, rising above surrounding trees, letting air currents reach inward to the buildings. All façades rising above ground floors are provided with large window openings. Wide eaves that go all around the building protect walls against rainfall. Although the multitude of spacious windows would

usually require shading against solar radiation, solutions to that end are not emphasized in this region, since cloudy days number as high as three hundred a year. Furthermore, there is also the need to keep indoor spaces luminous (Aran, 2000: 102, 104, 108) (Image 7.12).

7.2.3. Mediterranean Mountainous Climate

In central Anatolia, colder winters of the Mediterranean mountainous climate prevail. Relative humidity is low and temperatures below the freezing point are common. Stone masonry walls with small window openings ensure insulation against cold weather and the maintenance of indoor temperatures.

In two-story houses the granary and stable are placed on the ground floor in order to heat the living and guest room on the upper story. Exterior windows, framed with thick cut stones, are small in size (Aran, 2000: 113).

7.2.4. Dry and Hot Climate

The dry and hot climate prevails in the continental Anatolian

Peninsula. To the south and west of Malatya (eastern Anatolia) settlements and buildings are sensitive to climatic conditions. Heated through the day, the air

Image 7.12. Timber plank house in Karaçam of Çaykara (Trabzon) and its veranda space (Anatolian Eastern Black Sea Region) (Aran, 2000: 108-112).



is dry and the reflection of solar light is intense from the light colored landscape. The sky is cloudless over a long period of the year, wind velocity generally rises toward noon carrying sand and dust, and the diurnal range of temperature is large. Rains are few and far between, and come during storms lasting only a few hours (Givoni, 1967: 343).

Some of the settlements in the dry and hot southern region consist of buildings of cubical masses. Exterior spaces that separate buildings maintain the togetherness of all buildings, including the ground.

Roofs are used for desiccating fruits and cereals, as workplaces. Outdoor activities are confined to early morning hours, afternoons, and night times. The inhabitants sleep on roofs or in courtyards on raised wooden platforms acting as bedsteads (Aran, 2000: 114) (Image 7.13).

7.2.5. Courtyard Houses in Anatolia

While in many regions of Anatolia the compact house without a patio is the norm, the house



Image 7.13. Narrow passageways and courtyard house in Yukarı Ulupınar of Darende (Malatya, Eastern Anatolian) (Aran, 2000: 116-117).

types oriented inwardly onto a cool courtyard are also present in certain regions. They derive from ancient northern Mesopotamia tradition and Islamic culture, and have been built in these areas for centuries.

The spatial layout of courtyard houses consists of rooms with *eyvans* around a fairly large patio. The fact that houses with outer and inner *sofas* are particularly common in cities illustrates the cultural contribution of the Turks in central Anatolia, where they first settled (Sözen, 2001: 67).

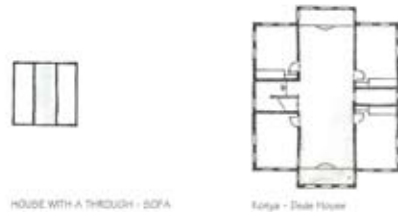


Image 7.14. Konya house with a roof veranda (above) and Antalya house with an exterior sofa (below) (Sözen, 2001: 84-85).

Konya houses with courtyards can have a kind of veranda, roofed and with closed sides but open at the front, onto which the rooms open directly (Image 7.14).

The most distinctive courtyard houses of the southeastern Anatolian region are in Ufa, Mardin, and Diyarbakır. In this region summer temperatures range between 40 and 45°C, and protection from heat is the main factor in design. Here numerous large rooms are placed around a huge courtyard, creating a house reminiscent of a small palace. The high exterior walls have few windows, giving them a plain appearance, but the interior spaces are richly decorated. In courtyard houses of Urfa an imposing main gate opens into the courtyard, which in some cases contains a pool to cool the air. Service rooms are on the ground floor, while the principal room and other living rooms are on the upper story. The principal room is at the corner of the long narrow balcony or outer *sofa*. Rooms encircling a courtyard as seen in southeastern Anatolia are also found in ancient Anatolian dwellings revealed by excavations. In these houses the

living spaces were arranged in an L shape around a courtyard. The houses of eastern Anatolia echo the architectural characteristics of Persia (Sözen, 2001: 69).

8. CONCLUSION

There is no single way to interact with climate factors in architecture. Most of the regions where Islamic culture spread have harsh conditions due to aridity, great insolation, and high temperatures during the day. Thus, to improve the environmental conditions for habitability, bioclimatic devices had to be developed to construct the best shelter with the lowest energy cost. In preindustrial times, the fossil fuels stored in the earth during certain geological periods were not available, and in dry regions vegetal fuel was in short supply. So this civilization had to develop bioclimatic skills and behaviors to make the most of natural conditions at any time.

These regions were also affected by the climatic changes reported from the 5th century. These changes were less intense than in the Atlantic North in temperature

terms, but rainfall changes can be detected. This factor could also be related with the fast expansion of Islam in the early times.

Dwellings typology in Maghreb was conserved between the 14th and 19th centuries, well adapted to hot conditions with its north-south orientation and water installations in courtyards, few windows to the exterior, and small and protected quadrangular patios, but also with some devices against cold, like the four covered porticoes of the courtyard. During the peak of the Little Ice Age in the 17th and 18th centuries, the chimney introduced in the kitchen tended to heat also some of the main north rooms. Vertical and

horizontal nomadism are well developed in the bigger houses. In Cairo, the deep loggias open to the exterior were placed inside the courtyard in 15th century and some of the wind-catchers that bring the breeze through the *iwan* and are related to the *qa'as* were blocked, remaining as a symbolic but not practical feature of a dwelling.

Other regions with remarkable bioclimatic devices are Baghdad and the coastal cities of the Gulf, where air-wells and wind-catchers were widespread, combining their effects with courtyards *iwans* and water. *Nasrid* architecture didn't develop these extraordinary devices, but cross-ventilation

and control of illumination were achieved perfectly in the patio, portico, and tower or *qubba* sequence in the most sublime palaces.

As in the Iberian Peninsula, Anatolia has diverse climatic patterns, but there the bioclimatic devices were often of secondary importance compare to other conditions such as views. In the woody regions with cold winters, the use of chimneys and fireplaces was widespread, one in each room of the compact house. The chimney breast is usually in an outside wall, and the remaining heat is not used in other rooms. On the other hand, in the hottest areas the courtyard arrangement

is provided to temper the severe summer conditions. In this case the solutions applied were diverse and influenced by different cultures, but keeping the main elements of the Turkish culture, as the inside or outside *sofas*.

Nasrid dwellings were the result of an intuitive process of background experimentation, developing what today we call effective bioclimatics skills applied in courtyard houses highly developed in this issue. *Al-Andalus* buildings have had a great influence and predominance in the Spanish patio tradition, surviving different forms and styles of architecture, and have been exported to other cultures.

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