THE MACHINE FOR LIVING VS. THE MACHINE IN THE GARDEN: NOT EXPERIMENTS FOR ARCHITECTURAL DECISIONS BUT ARCHITECTURAL CHOICES FROM EXPERIENCE

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INTRODUCTION

Thermal comfort as a scientifically determined term is relatively new in human studies, and one that continues to stimulate debate. This paper is intended to extend that debate. Especially the accepted definition by ASHRAE which emphasizes thermal comfort as a state of neutrality or indifference can be challenged as too limiting. Indeed, there is a vast human literature where the concept of comfort as environmental satisfaction, or life enhancement is potentially one of stimulation or heightened consciousness.

In this paper the engineering definition of thermal comfort is examined from an environmental point of view based on a series of well documented historical situations where people have open choices. The argument is that out-of-door conditions encourage very different parameters of comfort than when enclosed. And transitional environments, enclosures that are partly open, then require a transitional definition between enclosed and open settings. The elementary observation is that in overheated outdoor settings, much higher climatic readings provide comparable levels of satisfaction or enjoyment (comfort), than the upper limits for indoors. Whether the issue is overheated or underheated spaces, the degree of openness, access to the outdoors appears to expand the limits of comfort. The proposition is that open environmental systems provide a variety of conditions that are ultimately more satisfactory and thus more comfortable than tightly defined, thermostatically controlled comfort zones.

DEFINING COMFORT

> Webster's II New College Dictionary (1999) defines comfort (verb) 1. To soothe in time of grief or fear: console. 2. To make less severe or more bearable: relieve. Comfort (noun) 1. A condition of ease or well-being. 2. Consolation in time of grief or fear. 3. Help: assistance. 4. One that brings comfort. 5. Capacity to give physical ease and well-being. But the design professions are told to follow the narrow engineering definition of ASHRAE.

In effect the current ASHRAE definition of comfort, at the beginning of the chapter, Thermal Comfort, page 8.1, 2001 edition *ASHRAE Handbook of Fundamentals* which is very similar to 1997 text provides some hints of a much broader inclusion:

> A principal purpose of heating, ventilating, and air-conditioning systems is to provide conditions for human thermal comfort. A widely accepted definition is. 'Thermal Comfort is that condition of mind that expresses satisfaction with the thermal environment' (ASHRAE *Standard* 55). This definition leaves open what is meant by condition of mind or satisfaction, but it correctly emphasizes that the judgment of comfort is a cognitive process involving many inputs influenced by physical, physiological, psychological, and other processes.

> The conscious mind appears to reach conclusions about thermal comfort and discomfort from direct temperature and moisture sensations from the skin, deep body temperatures, and the efforts necessary to regulate body temperatures (Hensel 1973. 1981; Hardy et al. 1971; Gagge 1937; Berglund 1995). In general, comfort occurs when body temperatures are held within narrow ranges, skin moisture is low, and the physiological effort of regulation is minimized.
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> Comfort also depends on behavioral actions that are initiated unconsciously or by the conscious mind and guided by thermal and moisture sensations to reduce discomfort. Some of the possible behavioral actions to reduce discomfort are altering clothing, altering activity, changing posture or location, changing the thermostat setting, **opening a window**, complaining, or **leaving the space**.
>
> Surprisingly, although regional climate conditions, living conditions, and cultures differ widely throughout the world, the temperature that people choose for comfort under like conditions of clothing, activity, humidity, and air movement has been found to be very similar (Fanger 1972; de Dear et al. 1991; Busch 1992). *ASHRAE Handbook of Fundamentals*. 2001.8.1.

In the definition of "behavioral actions to reduce comfort", two acts are shown here in bold. Yet there are many instances where "opening a window" or "leaving the space" could exaggerate conditions, thus causing increased discomfort. Yet in the definition they appear to relieve the situation. To open the window or to leave the space for higher temperatures and humidity could be shown to be potentially detrimental actions. So is it the self-actuation, or is it the increased sense of openness that provides for better thermal satisfaction? I would propose that the concept of "adaptive models" (p. 8.18 *ASHRAE Fundamentals Handbook*, 2001) only partly explains human responses, especially in the dynamic settings of space variation, of degrees of openness, and access to the outdoors.

Indeed, it should be surprising that quality of space should have so little recognition as part of perceptual response. Space and the quality of its design is central to the theoretical examination of architecture as a human endeavor. Yet, in examining the symbolic, sequencing, and proportioning of architectural designs, the thermal or comfort or perceptual aspect is almost always missing. For instance, in *Symbolic Space* (Etlin, 1994) these words do not appear.

Similarly, the architecture, for example by Palladio or Frank Lloyd Wright, has an effusive literature based on the richness of architectural space, but without consideration of comfort. Especially in the designs of Frank Lloyd Wright and other modern masters, the use of glass and the inclusion of vegetation within the interior reinforces the spatial connection of inside with the outdoors, adding to the illusion of an extension of the garden.

SPACE AS A MODIFIER OF THERMAL RESPONSE

As a resident of a severely overheated summer climate, I have made many observations where people who have choices between "comfortable" mechanically cooled interior spaces and "uncomfortable" outdoor spaces that are numerically outside the comfort zone. Many chose the latter. Certainly, on a summer evening if you want to play baseball you will make that choice, even if the outdoor conditions are well above the comfort zone. But in social situations where the physical arrangements are similar inside and out, why do people chose to move outdoors to conditions unacceptable according to standards based on extensive statistically based experimentation.

More personal is the experience of leaving work after spending the day within an air conditioned office. The hot outdoor conditions, which are well above the comfort envelope, are welcome, and one drives home with open windows, or walks along with increasing skin temperature and rising perspiration but in great "comfort." I would argue that part of the explanation has to do with spatial as well as thermal stimulation. Having spent most of the day indoors seated in a small space within temperature controlled conditions, one chooses an alternative that enriches perceptual experience by its contrast, both thermally and spatially. Thus, I would argue that openness, lack of enclosure, is a perceptual condition that strongly affects expectations and thus provides a measure or prediction of

thermal satisfaction that is a distinctly different environmental set from those accepted for enclosed spaces.

Here is a **statement of the two paradigms**. The "Machine for Living" is the well conditioned refrigerated office with its controls set to provide neutrality and all environmental parameters bounded within a comfort envelope. "The Machine in the Garden: is me driving through 40 C degree heat with the windows open, the refrigerated air conditioning off, and enjoying all the stimulation, the openness and even my rising skin temperatures and perspiration.

OUTDOOR COMFORT

In most of the religions of the world, paradise is described as a garden, as an outdoor space resplendent with sun and shadow, flowers and trees, pools and fountains, with gentle breezes of perfumed air. No one imagines paradise as a perfectly comfortable architectural box, regardless of the perfection of its architectural or environmental design.

Within the last decade or so there has been a dramatic increase in studies about outdoor comfort. Especially the examination of urban microclimates and the opportunities for designers to modify outdoor environmental conditions have resulted in many technical publications, as well as physical interventions. And while these design activities obviously push conditions toward the accepted comfort zones for enclosed spaces, there appear to be no acceptable standards for the conditions of outdoor spaces. Rather, there are upper limits in which strong discomfort ultimately becomes the warning light of thermal health threat.

Characteristic of many recent exploratory papers that challenge the concept of comfort as a thermally bounded condition is in the Proceedings paper: "Holes in the Fabric of 'Comfort': What One's State of Mind has to do with One's Bodily State." The authors, Judith H. Heerwagen and Dean R. Heerwagen, describe "A Sensory Feast", the varied conditions of a sunny afternoon in an urban park in early summer. Especially important, they provide some 40 references in the scientific literature between 1961 and 1985.

In contrast, this paper is based on personal observations and published records about several historical periods in the domestic architecture of England and the USA from the sixteenth into the twentieth centuries. As a foil, two recent greenhouses are compared with a bioclimatically designed urban landscape. The hypothesis is that when people have choices that are not hampered by economics or status, they do not automatically seek space with more comfort control. Rather, they choose space and sense of spacious openness, with its implied or real attachment to the natural world. In selecting historic and recent cases, the criteria were to identify large scale patterns in which a major variable is openness and association with the outdoors, the ultimate openness.

As Nick Baker as observed, "We are all outdoor animals." Human life has evolved over 2000 centuries, almost all of it living outdoors. Only within the last few generations have we had the technical ability combined with the desire to provide totally controlled environments. The question is: Why should we want to? Do we really prefer to live within a perfectly controlled machine when we could live in a generously variable and interesting garden?

Recently, the publications of Nick Baker, Gail Breger, Humphreys and Nicol, and many others have applied rigorous scientific methods in documenting comfort not in controlled testing chambers, but in real buildings and built environments.

CASE 1. THE GREAT REBUILDING OF THE ENGLISH HOUSE

The advent of the Renaissance in England predictably brought a stylistic change in architectural expression. But more fundamental was a shift in the configuration and technologies of the ordinary house. That shift has been called The Great Rebuilding. Up until the middle of the sixteenth century, the medieval house of both aristocrats and of ordinary yeomen consisted primarily of a central hall, two stories in height up to the underside of the gabled roof. Service rooms on one end were separated

by the open hall from a ceilinged ground floor parlor on the other end. This medieval hall had a fire in the center of the floor, and openings high in the wall or roof to let out smoke. These windows might have bars and shutters but no glass.

The traditional hall-house was an enlargement of the Saxon hut. Under a thatched roof supported on a timber framework with walls of wattle and daub were gathered the head of household, his family, his servants, and sometimes his livestock around an open hearth. They lived together in a very open shelter where doors and shutters, as well as fire, needed constant tending. Especially the changeable weather of England meant that keeping a house was like sailing in shifting seas.

Typical examples are rebuilt houses in the Weald and Downland Open Air Museum at Singleton, West Sussex, England. Bayleaf Farmstead, originally built at Chiddingstone, Kent, is dated to 1405-30 when the open hall and service end of the house were attached to an earlier structure. (Figure 1) The hall is two bays wide and is open to the underside of the roof. The lower bay has no windows. The upper bay has double height windows that throw light on the high table where the head of household would sit in the center. Beyond the hall is a chamber with a flat ceiling. Above is the solar, the master bedroom.

The "Great Rebuilding" of the English house is most characterized by the advent of chimneys and the enclosure of the hall with a ceiling that provided flooring for chambers located on the floor above. The use of chimneys and a hood or fireplace to contain the hearth allowed the fire to be better controlled. With the use of glass in windows the operation of the envelope of the house was totally changed. The "crown glass" method of medieval glass blowing was only introduced into Britain late in the seventeenth century from Normandy. The number of specialized rooms increased and there was a use of finer materials such as cut stone instead of dry stone walls. Bricks became common first for fireplaces and chimneys, then for constructing the whole house. The number of rooms in late sixteenth century Kent increased from three, to five, six, or seven in less than two generations. While this redefinition of household amenity was technical, the result was a significant shift in how the new "civilized" houses were used in comparison with older vernacular houses. The classic quote is from the 1577 *Description of England,* by William Harrison's view as an Essex village rector*:*

> There are old men yet dwelling in the village where I remain, which have noted three things to be marvelously altered in England within their sound remembrance…One is, the multitude of chimneys lately erected, whereas in their young days there were not above two or three, if so many, in most uplandish towns of the realm (the religious houses, and manor places of their lords, always excepted, and peradventure some great personages) but each one made his fire against a reredos in the hall where he dined and dressed his meat.

However, while the Great Rebuilding provided a new English house type, the old was not eliminated. The reports of diarists and antiquaries document the parallel existence of the old way of living, the persistence of the open hall and parlor by those who had means and thus choice. New versions of the old hall house continued to be built. The archaic typology was the central open hearth: "hearths in the midst of the room for chimneys, which vented the smoke at a louver in the top," "fyer in the middest of the howse against a hob of clay." But this persistence of medieval vernacular architecture with halls and open central hearths were now built with more permanent construction.

Roger North in 1698, a century and a half later appreciated that these were **choices of how to live** and not issues of progress about comfort.

> …It is likely the world anciently, being nearer the state of nature, might less vary according to nations, than since arts have taken place, and invention a buissness. A great room for the family, was the chief of the house, and there with a fire in the midst the family past their time, and probably cook't and eat in the same room; and it may be sleeping there too, was not unusuall; but when at one end of this great room, another was added for kitchen, with a chamber for the lord and lady, it was compleat; and little more was thought of for divers ages of men. Then negotiation and buissness suggested another room at the other end of the house, called a parloir, which signifies a place to discourse in. This was the lord's withdrawing room, and soon gained a

> room over, for a stranger to lodge in. And then adding to the kitchen a buttery and pantry, that is offices for the drink and bread, the economy was fully supply'd. (Colvin, 65)
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> …And therefore beauty is not onely relative to the severall conditions of men, but also to the severall modes of living which different ages and countries affect. As for instance in the ancient or Gothick times it was the modes for numerous familys to eat in the same room at severall tables and have few waiters; the butler for serving the master's table, and the porter the others (for the gates were all closed at that time) was sufficient. And this was not onely the use of England, and other nations the Greeks and Romans called barbarous, but by Homer wee may observe the like method in the Grecian countrys. And the Romans use to eat in the porticos next the streets, shewing to the people (whom ambitious warrs kept poor enough) that their senators were content with a spare dyet. But that way of a common eating room made great halls open to the roof, with a lanthorne, to lett out smoak and stench, a laudable fashion, an consequently an indication of great dignity and plenty, and excuseth the unclenlyness of it; but at present the way of the world is chang'd, and the eating is devided, many servants wait, and take their repast after the master, who is served at a table in a room layd out for that porpose. Therefore those wide halls are layd aside, and in the room of them comes the *grand salle*, which is a place to entertein persons coming to the house, and therefore ought to be well adorned, and neat…(Colvin, 125-126)

While to our way of thinking, the hall with an open hearth may be primitive, irrational, and dysfunctional, it had attributes especially of openness, of natural light, and if well tended, to be well ventilated and airy. The hall and hearth is a typology that has a parallel in many other cultures. The smoke exposed upper parts of the room and thatch roof had a natural preservative and pest control. In contrast, the new closed houses that theoretically offered much better environmental control could be stuffy and poorly lighted with their low ceilings and small windows, closed with glass. The new enclosed room with fireplace could also be smoky, a nuisance and a health hazard that continued in some of the best houses of London and England up through the end of the eighteenth century. Many medieval open hall houses with no separate rooms were remodeled with second storey rooms inserted above what was once an open hall, and the insertion of brick fireplace and chimney and walls. Thus there were more rooms within the same exterior envelope.

Again, the two paradigms are present, here in the two styles of house. The medieval "hall and th" house has a single large, spacious room with large controllable openings. The outdoors is invited inside. The interior is a mediated version of the outdoor garden. But the new "lobby and parlor" house with its low, flat ceiling and more controllable fireplace is an attempt at closing the house and turning it into a machine that excludes the garden idea of the outside. Tighter controls presumably mean a tighter operational tolerance. This environmental intolerance presumably is part of the performance expectation that disassociates architectural enclosure from the openness of the controlled garden experience.

CASE 2: GEORGE WASHINGTON AT MOUNT VERNON

In 1751 when the young, impressionable George Washington (1732-1799), aged 19, visited Barbados, it was his only trip outside mainland America. He was escorting his half-brother, Lawrence, 14 years his senior, on a trip for the cure of his respiratory illness. While looking for accommodation, George thrilled at being "perfectly ravished by the beautiful prospects which on every side represented to our view the fields of cane, corne, fruit trees, in a delightful green." He rented a hillside villa outside Bridgetown from a fellow British officer, Captain Croftan, commander of James Fort. There he experienced the extensive British use of porches in warm weather climates.

> As permanent military and naval forces became part of the national strategies of France and Great Britain in the eighteenth century, preparedness for war depended critically on the health of troops and sailors. In the eighteenth century, warships were more dangerous to the men aboard them than to the enemy whom they battled, just as troops were more likely to die from life in barracks than on the battlefield. Commanders dealt obsessively with questions bearing on

> the health of men in their command—particularly questions of cleanliness, diet, and ventilation—and seized on expert opinion in such matters. (Crowley, 239)

Thus, porches or verandahs were introduced in military buildings as accommodation for overheated climates. Piazzas became a regular feature in military hospitals and quarters in India, but especially in the West Indies. So

> when the Royal Navy built permanent facilities for naval stores and careening yards on Lynche's (later Navy) Island at Port Antonio, Jamaica, in the early 1730s, a structure with a verandah, presumably quarters for officers, crowned the island's hilltop. Shortly thereafter double-storied civilian houses with verandahs appeared, judging from contemporary illustrations. (Crowley, 240)

When Lawrence died the next year, George was named as residual heir to Lawrence's Virginia estate at Mount Vernon to succeed Lawrence's widow, Ann, and their only surviving child. But when young Sarah died in two months, George, at the age of 20, rented Mount Vernon and began improvements on one of the best Virginia estates. He first enlarged the house by raising the roof for a second storey in 1759 when he married Martha Custis. With the death of Lawrence's widow in 1761, George Washington became sole owner. In the late 1770s, Washington built the "piazza" at Mount Vernon, its most distinguishing architectural feature. Extending the full length of the house that he doubled in size, the river façade overlooks the Potomac from a bluff 126 feet above the water. By enlarging the family medieval farm house built by his father in 1735, George Washington multiplied a modest house into a prototypical Chesapeake Bay plantation house. Thus, a retired national hero created a new setting for his self-image, and his plain "republican style of living." Ten years later he was sworn in as the first President of the USA. When he died in December 1799, Washington had enjoyed more than two decades with his piazza. He had built "a lofty portico, ninety-six feet in length, supported by eight pillars, [which] has a pleasing effect when viewed from the water." Thus, the private home of the first president was a major example of architectural accommodation for the appreciation of the "picturesque" in nature.

His visitors usually called it a portico because that came closest to their idea of such a structure attached to an ambitious house. But Washington referred to it as a piazza and a "long open Gallery" because he intended it to be a social space, not a token of Palladian style. He used English flagstones to pave the piazza to integrate it with the landscape garden while providing a partially sheltered space for informal leisure and entertainment. It was an important setting for many memorable conversations with distinguished visitors, and especially for afternoon tea. George Washington was well known for his hospitality. Entertaining visitors and guests was an important part of the "domestic enjoyments" at Mount Vernon, and the piazza was the favored location.

To those educated in Palladian refinements, George Washington's piazza was somewhat as plain or awkward as he himself sometimes was. But it was a landmark in American domestic architecture. Its influence cannot be isolated. It was part of an environmental sensibility that included pleasure and comfort in the uncontrolled openness of outdoors that evolved as a cultural characteristic of a segment of the American population. Already within his lifetime, Mount Vernon was the subject of professional studies such as sketches and notes by Latrobe in 1796, as well as by popular and sentimental paintings. For instance, "The Home of George Washington, 'The Father of the Country,'" was painted in 1797 by J.Weiss. The neo-primitive painting, "George Washington at Mount Vernon," is signed on the back, "Painted by A.M. Tredwell at Mrs. Willard's School of Middlebury, Vernon, 1814." Both are views of the open river side in which architectural details are accurately painted.

The importance of that architectural imagery was reinforced in the nineteenth century. Ann Pamela Cunningham's Mount Vernon Ladies Association of the Union began the purchase in 1858 and the restoration in 1859 of Washington's home. Thus, they initiated the American preservation movement by focusing on an architectural icon that was a private model, not an official building. It was part of a growing sensibility that popularized temple-shaped buildings with a portico or porch that characterized the American house of the latter part of the century.

At the World's Columbian Exposition in Chicago in 1893 Virginia was one of several states that produced pavilions based on their own architectural heritage. Virginia had the "exact reproduction" of Mount Vernon by architect Edgerton Rogers (1860-1901). But photographs show that he embellished some of the details and even added another porch, this at the entrance. As a popular success, the duplication of Washington's home had many applications. As a state pavilion for national and international expositions it was seen in 1915, 1931, and 1932. The primary architectural icon of the most prominent American hero is not an "oval office," or a fireside chat location, or a great hall, but a porch. George Washington's piazza continues to popularize a grand vision of the American suburban dream.

CASE 4. THE AMERICAN BUNGALOW

The prototype for the modest American suburban dream home, the bungalow, came almost a century later. Its single storey form always includes a sitting porch or verandah as an outdoor room. The bungalow was derived by the British in India from the "banggolo" or peasant hut of rural Bengal that was popularized in British resorts starting in the 1850s. It entered the USA as a vacation cottage type in the 1880s, and became an American suburban house starting in southern California around 1910, thus promoting outdoor living with a furnished outside room.

CASE 5. THE NEW GREENHOUSE AND BIOCLIMATIC URBANISM

A series of recent greenhouses demonstrate the prowess of modern technology to enclose and to condition large gardens. Both Biosphere II built near Tucson, Arizona, USA in 1986, and the Eden Project in Cornwall, UK opened in 2001 have received world-wide attention. Both are very large transparent/translucent enclosures that capitalize on daylight but are thermally driven by colossal mechanical systems to produce a variety of internal microclimates with biologically distinctive zones called Biomes. These totally enclosed biological systems are compared with an open system of bioclimatic urbanism, EXPO '92 at Seville, Spain. All of these recent projects deal with the design interface of garden and architecture, extending the idea of building a paradise on earth.

Biosphere II began with land acquisition in 1984 in the Sonoran Desert of Arizona at latitude 32, and climaxed by sealing eight human subjects called "biospherians" inside an enormous greenhouse for two years in 1991. With the less than triumphal re-emergence of the "biospherians" the project entered a period of catharsis in 1994. Columbia University of New York City was given the responsibility to reconstitute the project in 1995. With more than 6,500 glazing panels enclosing an area of more than three American football fields and a volume of more than three million cubic feet, this is one of the more ambitious scientific environmental experiments ever attempted. (Cook, 1996)

An energetically and informationally open but materially closed structure, Biosphere II contains seven ecosystems including a human habitat and an intensive agricultural system. Other ecosystems are: freshwater, saltwater, desert, savannah, and rain forest. The 3.15 acre (1.25 hectare) "miniplanet," which includes a tiny ocean, savannah, and 3,800 species of plants and animals, was sealed on September 26, 1991 for its signature two-year experiment. The project, financed by Edward P. Bass of the Texas oil family, is officially said to have cost $150 million. But some outside estimates have placed the cost closer to a half-billion dollars. Biosphere officials said beforehand that this is not pure science by a science-oriented business.

> From the outset, Biosphere II had mixed missions: Terra-forming Mars or the Moon, understanding Earth; educating (and entertaining) the public about biospherics, while simultaneously implementing the new science called biospherics. (Warshall; 1996)
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> Ecodesign: The architecture was embroiled in egos and ignorance. Advocates of beauty duked it out with advocates of the protoplasm. The result was totally human. The location, called Biosphere II, at a latitude of strong solar seasons with the need for more light in winter and more cooling in summer. The giant glass greenhouse sat in a valley. It missed dawn and late afternoon sunlight—reducing the flow of photons to Bois II plants. It had north-south

> orientation, so the southern desert was swathed in radiance but the rainforest contracted the winter chills…
>
> In short, Bios II's location, orientation, glass, framing struts and walls, flat-surface dust, ice, algae, and grime, and the glass itself transformed the building into an anemic photosynthesizer, powered by less than half of the local photon flow, churning out perhaps 20 percent less oxygen than the "real world." In ecodesign terms, humanoid infrastructure—growing lamps for more photons, air conditioners to warm or cool the interior, air handlers to distribute the heat by artificial wind, the impossible task of window washing, and electric energy (from diesel or the grid)—had to replace sun power and a sunnier site location. (Warshall, 1996)

The Eden Project, opened in 2001, was created as a spectacular theater to tell the story of human dependence on plants. But to date there is little storytelling, and although there are supposed to be over 135,000 plants of approximately 4,500 species, they are still immature and hardly established. Claiming to be the largest greenhouse in the world, Eden is hidden in a disused china clay pit, 60 m (200 feet) deep in rural Cornwall, the southwest end of England. In spite of its dramatic cathedral quality, Eden can be a claustrophobic experience.

On the interior are: 1. Warm Temperate and 2. the Humid Tropics, each in its own greenhouse, linked by an entrance pavilion covered by a grass roof. On the outside is a large and comfortable landscape contained within the disused pits that provide wind protection and thus a more temperate or moderate climate than if exposed. This outdoor setting is probably the most exciting and memorable experience.

Designed by architect Nicholas Grimshaw of London, the Eden Project attracted more visitor while under construction than did the Millennium Dome during its one year run. Although only opened in April, by midsummer of 2001 the Project took out newspaper advertisements not to visit because it is so overcrowded.

Setting aside architectural attractions, consider these giant greenhouses of 1986 and 2001 as Machines with Gardens inside. In effect, the architecture only encloses and brings in daylight. But it is the mechanical plant that does the work. From that point of view, they are no improvement on the Crystal Palace of 1851 which had no mechanical system. Rather, the Crystal Palace was like a sailboat. By opening and closing various architectural windows, one could control the temperature, humidity, and air exchange. Thus, a century and a half ago, the Crystal Palace was kept within tolerable interior conditions of the limits passively, while providing space for full-grown elm trees.

EXPO '92, Seville, Spain. In contrast to the enclosed greenhouse with its mechanically engineered climates is the bioclimatically designed exterior space such as represented in the outdoor design for the 1992 world fair at Seville, Spain.

> La Cartuja Island, where the EXPO '92 was celebrated, was the testing ground for the bioclimatic techniques which specifically employed the hydrothermic treatment in the outdoor spaces. In accordance with their particular function, different areas were (conditioned) in varying degrees so as to create a feeling of physical well-being almost comparable to the indoor air-conditioned spaces, all of which would be used by the millions of visitors expected to visit the fair. (López de Asiain)
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> The Universal Exhibit of Seville (EXPO '92) took place between the 20th of April and the 12th of October to commemorate the 500th anniversary of the Discovery of the New World from Spain. The site was a wasteland of 215 hectares located on the Isla de La Cartuja, a tract of land surrounded by the two branches of the Guadalquivir River. Five grand avenues which measure 300m x 800m (1000' x 2667') completed the area designated for the pavilions of the international participants. A pedestrian route 2 km long linked various theme pavilions. Those pavilions representing the different regions of Spain bordered a semicircular artificial lake 15 hectares (42 acres) in size.

Normally during the period between the 15th of June and the 15th of September the climatic conditions in Seville on the whole remain well above comfort levels and can be almost intolerable. Even in May, June, and October the temperatures can go very high, creating problems for those people who are not accustomed to the heat. The need of passive cooling of the outdoor spaces of the EXPO, therefore, was a main concern. A team from the Department of Bioclimatic Architecture of the School of Architecture of Seville (SAB) studied the means of bettering the climatic conditions during these months, by the use of shading structures, the special utilization of water, thick vegetation, and systems to promote the movement of air.

EXPO '92 was comprised of:
An auditorium with a seating capacity of 6000.
A cinema with a capacity for 1200 people.
A theater with 1000 seats.
A Palenque: a large, covered, air-conditioned plaza to seat 3000, containing 475 m2 of gardens.
8 uncovered auditoriums.

Vegetation:
350,000 trees and plants
40 km of hedges
Shading by hydroponic vines on pergolas over 50 h (50,000 m2)

Water: 20 h of fountains, cascades, ponds

It was necessary to plan avenues, walkways, areas of vegetation, resting zones, parking and areas of access which would truly alleviate the extreme temperatures and conditions of the hot Seville summer, and, keeping with the Andalusian tradition of cities and gardens like Medina Azahara, la Alhambra of Granada, etc., would at the same time incorporate the techniques and components of the most advanced passive solar techniques: systems for the micronization of water, evaporation of humidity, (cooling towers), (wet walls), cybernetic fountains, water-cooled pavements, underground ducts for the cooling of air, etc.

Traditional devices were used for producing shade, trees and other vegetation, cooling by running water, ponds and fountains, large awnings or canopies covering large areas, along with the most modern systems of artificial fog, production of cool air, computerized control of temperature and relative humidity, hydroponic cultivation for the construction of large surfaces of pergolas covered with greenery, etc.

The passive or natural methods employed were closely related to those of historical Andalusian examples of architecture: La Alhambra in Granada, Medina Azahara in Cordoba of the Alcazar of Seville, and they corresponded technically to the new ecological paradigms of the XXI Century, as defined in the guidelines of the SAMA.

Financially, EXPO '92 was disappointing for reasons beyond the design and accommodation of the outdoor design. In fact, the most memorable artifact of EXPO '92 was the design of the outdoor spaces, both architecturally and experientially from its bioclimatic design.

SUMMARY

This selection of historical events in the experiences of vernacular house design demonstrates that the quest for comfort is not a universal or consistent pursuit. For those who have the means and for those who have been shown alternatives, decisions about the quality of accommodation are not always toward a greater degree of control, but rather may be based on quality of the experience. Thus, the openness of the medieval English hall house may be preferred to the lobby and parlor with fireplace and chimney of the English Great Rebuilding.

Simultaneously, the technical construction improvements of the Great Rebuilding were especially resisted in the American colonies. Although the New World climates were more rigorous, and

although poverty was not the reason, yet flimsy construction similar to English cottage construction persisted. In most cases, the discomfort was on the cold side, primarily instances where the burning of fuels would be increasingly ineffective. Alternatively in the evolution of the verandah or the piazza, a great military and political figure, George Washington, popularized an architectural feature in an overheated climate at a time when no mechanical devices could deliver comfort. However, clearly Washington and his many imitators used the verandah or porch on many occasions, not just when outdoor conditions were less stressful. Thus, a choice of "openness" was added to the domestic vocabulary. The California bungalow popularized outdoor living and the openness of street space at a more modest scale starting early in twentieth century American suburbs.

In the late twentieth century, major technical investments allow the design of very large greenhouses that, in effect, bring foreign climates and their exotic biota indoors. The environmental machine has swallowed the garden, but at great expense, and at some human and biological discomfort. In contrast, the distribution of bioclimatic natural techniques within a large urban garden, such as at EXPO '92, demonstrates how the outdoor climate can be tempered to provide a much richer and freer intervention than a greenhouse. EXPO '92 demonstrates a rich direction for environmental design in moderate climates for both domestic and urban scale spaces.

In summary, there appears to be a strong case for a much broader climatic definition of comfort, especially when informed choices are available. Openness as an experiential quality and association with natural climates appears to be a major factor of environmental satisfaction. Repeatedly in the evolution of English, New England, and tidewater colonial domestic architecture, openness was a distinguishing quality. And in the increased interest in pleasant public spaces the greenhouse may be superceded by bioclimatic urbanism.

CONCLUSION

In our present mechanical use of only climate measures to define human comfort, we seem to have mislaid the architectural/spatial context of human existence briefly examined here. But how do we measure the influence of space and the outdoors as a factor of human comfort and well-being to expand the climate envelope? And how do we account for this other set of more immeasurable factors to provide more comprehensive standards. What is the place of the garden as an ultimate ideal of paradise in our extended goals for "comfort?"

POST SCRIPT

This study of the architectural determination of comfort was done without reading Leo Marx, *The Machine in the Garden*, 1964, which deals with the philosophic acceptance of technology within the American pastoral idealism. Similarly unread was Claus Emmech, *The Garden in the Machine*, 1991, in Danish, 1994 in English, that deals with the emerging science of artificial life.

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