IMPLICATIONS OF SOLAR RADIATION FOR INTERIOR DESIGN

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INTRODUCTION

From the beginning of history man has loved the sunlight. Ancient religions worshipped the sun god, Ra, and even as late as the Greco-Roman civilization the sun gods were high in the divine hierarchy. Many scholars, from Aristotle to Montesquieu, believed that climate had pronounced effects on human physiology and temperament. In contrast today, the sun has few worshippers, but the significance of its emotional importance remains. Ellsworth Huntington hypothesized and ranked climate with racial inheritance and cultural development as one of the three great factors in determining the conditions of civilizations.[1]

Julian Huxley compares the events of early civilizations with that of dry and wet epochs as they relate human history to climate. He believes the shifts in climatic belts have economic and biological effects and these effects hold the balance for populations.

As these belts shift, migrations occur which in turn bring not only wars but the fertilizing exchange of ideas necessary for the rapid advancement of civilizations.[2]

As civilizations have advanced, accumulated experience and ingenuity have diversified shelters for man to meet the challenges of the climatic variations. The problems of man controlling his environment and of

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[1] Ellsworth Huntington, Mainsprings of Civilization (3rd Edition), (New Haven, Conn.: Yale University Press, 1945).

[2] Julian Huxley, Man In The Modern World, (New York: Mentor Books, The New American Library, N. Y.), pp. 61-73.

co-ordinating conditions favorable to his objectives and activities are as old as creation itself. Throughout all civilizations, in the building of shelter, men have searched to fulfill two basic human needs: (1) protection from the elements and (2) provision of an atmosphere favorable to spiritual endeavor. Each period appears to have had its own particular philosophy of house design, and the architectural crystallization of each time is a faithful mirror of its special thought and feeling.

The entire history of shelter engineering reveals a continuing effort by mankind to provide an interior climate that reproduces as nearly as possible, the climate to which man is best adapted, i.e., the climate of his place of origin. Markham points out that research directs us to the proximity of the seventy degree Fahrenheit annual isotherm as the probable location of man's original habitat.[3]

Animals of high and low form possess natural defenses against wide ranges of unfavorable climates; for example, the bear, the elephant or even tiny ants can withstand wide climatic differences. In contrast, the physical flexibility and capacity of man for climatic adaptation are relatively weak when compared to those of many animals. The ant exceeds all animals with their individual efforts for shelter by collective building. The towers of the ants are prodigious--reaching 400 times their body length which is ten millimeters--and when translated into human terms would equal two thousand four hundred feet in height.

Man may be the highest species of the animal kingdom, the most intelligent, and a superb triumph of evolution, but man is comparatively inferior to other animals in the control of body temperature. Many

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[3]Sydney Markham, Climate and The Energy of Nations, (London: Oxford University Press, 1944), pp. 9-10 BRI.

animals can suffer a change of ten degrees in their body temperature without inconvenience or distress, but man must keep his body temperature near ninety-eight and six-tenths degrees Fahrenheit or die.[4]

Biological evolution apparently stopped with man. It has required the inventions of clothing, fire, shelter, land, and water transportation, and other variances before man was able to become--despite minor phyciological characteristics of skin color, etc., -- one species.

Through years of research authorities believe this occurred because man elected to control his environment, he made natural forces work for him rather than submitting to the natural route of survival by the mutation circuit. Instead of changing to fit his environment, man through the centuries has changed his environment.

Skeletons of prehistoric man reveal an average age of approximately eighteen years. Ancient Roman archaeological studies indicate an average life of only thirty-three years. Current studies indicate man may have a life potential of 125 to 175 years. However, we know men die before reaching half of this potential, due largely to the effects of hostile environments and man's inability to control them.[5]

The critical interior temperature of man controls his life expectancy, and this is largely dependent on man's control over his external natural environment--actually his control over the direct and indirect effects of solar radiation.

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[4] Ibid.

[5] Henry L. Logan, "Light for Lighting", Illuminating Engineering, Volume 42, No. 3, pp. 291-319. (1947).

THE SEASONAL CLIMATIC VARIABLES

Many segments of the environment of man affect him. The seasonal climatic variations effect on man's physical and mental activity have been studied by Ellsworth Huntington of Yale University. The studies and research he has done show different effects of the variables on man and his productivity.

Temperature

The research shows that a lower ambient temperature is desirable for mental work, as contrasted with physical work. Thus, an indoor climate favorable for academic or office work is not necessarily the same as that which would promote optimum physical activity. Huntington found that excessive dryness of indoor winter atmospheres (those drier than the majority of the deserts) produced a drop in physical activity. Hence as the outside air warms and windows are opened to counteract the lack of interior humidity, human performance increases to a peak in June, but drops under the influence of the excessive heat of summer. With the lowering of temperatures in the fall, human performance resumes its rise to a peak in November, but with the winter temperatures and accompanying dryness, performance declines to a low in February. However, with proper indoor climatic controls the wide variations in temperatures and humidity would not occur, thus, human performance would remain at a high level of productivity.[6]

Detailed studies reveal that human activity declines at both low and high temperatures and reaches a maximum between the range of 59

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[6]Ellsworth Huntington, Civilization and Climate, (3rd Edition), (New Haven, Conn.: Yale University Press, 1941.)

and 70 degrees Fahrenheit for physical work in the temperate zone. The optimum temperature becomes higher as man moves to more southerly climates; however, the variation in the optimum temperature is very little, less than 10 to 15 degrees Fahrenheit.

Humidity

Humidity does not seem to be responsible for work fluctuations except as it is influences by temperature. However, humidity is significantly influenced by temperature. During the winter season the air in a space enclosure has a possible humidity of 60 to 65 percent, but most of the time the humidity is actually 20 to 30 per cent. A low percentage of humidity (20 to 30 percent) dries the mucous membranes and greatly increases susceptibility to colds. It is one of the most important factors in high death rates during February and March.

The colder the day the lower the percentage of humidity. Outside air at 14 degrees Fahrenheit, with all the moisture it can possibly hold, when warmed to 70 degrees Fahrenheit will have only 12 percent humidity, such are the pertinent implications for merely warming cold outside air. Humidity is influenced by temperature and is another variable that must be controlled for optimum mental and physical performance. Therefore, a humidity control device is required to complement this interrelationship between temperature and humidity.

The Effect of Light

It has been shown that the increased natural light available from the end of January to the end of May increases work output at a faster rate than could be attributed alone to the rising temperature and more favorable humidity conditions. However, after May with adequate natural light available throughout the summer, the effect on work output is largely the combined result of temperature and humidity.[7]

Artificial light makes the situation more complicated and differs from daylight in relative percentage of infra-red radiation. Discomfort caused by infra-red radiation from incandescent lamps is definitely felt at a horizontal illumination level of 125 footcandles, and at about 500 footcandles with fluorescent lighting. The infra-red at this level is comparable to a daylight level of 900 footcandles. Naturally, as the individual becomes uncomfortable his work rate declines.

Uniformity

Any climatic condition maintained steadily due to direct and indirect effects of solar radiation produces a uniform, monotonous climate; continued uniformity with respect to this variable causes a decline in man's energies and in his physical well-being.

Such a decline of productivity can be terminated by a moderate change in temperature, humidity, air movement, or light. Variation in external stimuli seems to produce better production and consistent work. Research has indicated changed temperature as the largest tonic effect factor.

Static Atmospheric Charge

A vital part of the systematic procedure involving good design includes the field of bio-climatology which compiles data dealing with

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[7]Logan, *loc. cit.*

human biological reaction to such variables as the electrical charges in air, the effects of air pollutants, and barometric pressure changes.[8]

Researchers determined the "stuffiness" of air conditioned and heated air-tight homes is caused by air particles which are more positively charged than normal. Negative ions number about one-third fewer in heated or air-conditioned spaces than in the outside air. The negative ion count in outdoor air varies from hour to hour and season to season.[9]

A positive charge of static atmospheric charges has a deleterious effect on health, however, a negative charge has a desired beneficial effect. Therefore, a human being feels his best at a time when the atmosphere is rich in negatively charged ions.

Air Movement

Another significant design factor is air movement. Air movements affect the cooling process of buildings, humans, and their surroundings. The temperature does not decrease, but a cooling sensation is due to heat loss by convection and due to increased evaporation from the human body.[10] Careful wind analysis is required in most climatic zones due to varying conditions which prevail. Such air movements need be utilized for cooling in heated periods, and as a relief from vapor pressure during times of high absolute humidity.

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[8]Eugene A. Sloane, "Can Negative Ions Added to the Air You Breathe Improve Your Well-Being?", House Beautiful, Volume 103, No. 2, pp. 81-82.

[9]"Conditioned Climate: The ABC's", House and Garden, No. 1 (January, 1965), pp. 134

[10]Victor Olgyay, Design With Climate, (Princeton, N.J.: Princeton University Press, 1963.), p. 19.

Desirable breezes can be distinguished from unwanted winds and their directions and velocities easily summarized. Dependent on their characteristic duration and velocity, they can also be expressed as orientation vectors. If the maximum-velocity air flows are too high for comfort, and a balance can not be reached with the heat or vapor pressure conditions, mechanical conditioning should implement.

Wind protection can be provided by windbreaks and positioning of the building. Natural ventilation can be utilized in the following ways: by orientation; use of the surroundings to create low and high pressure zones; locating inlets to the building high, outlets in low pressure areas; small inlet and large outlet sizes; inlets which direct the flow to the living zone; and by using an open plan undisturbed interior flow results.

All of the climatic components directly influence the energy, health, safety, and longevity of man. A complexity of environmental interrelatedness and physiological comfort exist, thus the design of our buildings alone might well provide an unimpaired physiological performance zone for humans which would yield greater national prosperity and health.

PHYSIOLOGICAL EFFECTS OF THE VARIABLES

The inconstancy of man's natural environments, a dangerous variability, has evolved external instruments developed by man for regulating the relationship between his body's need and the violent fluctuations into which he migrates.

The physiological implications related to the thermal effects of solar radiation in man relate to changes in skin temperatures through thermal conductivity, density, and optical properties of the skin, and specific heat of the living skin. Change in skin temperature level is an important factor in perception of warmth and coolness, and the skin temperature level also has a stimulating effect on skin blood flow. Pain and thermal injury may occur when solar heat radiation raises tissue temperatures into the danger zone, about 113 degrees Fahrenheit. "The range in which man can operate efficiently and maintain health over long periods of time, the optimum range, that is, is very much narrower than the total range which man can accept. Hostile natural environment for the human body causes an acceleration of the aging process through capillary ruptures, impairment of circulation, tissue breakdown, and thus, hyposia (lack of oxygen delivered) to the brain."[11]

Such clinical evidences of research in the thermal characteristics of the human skin give evidence of pain which causes local inflammation; reflect effects such as change of heart rate, respiration rate, glandular secretion, and state of nervous hyperexcitability at the spinal cord level. All of which affect the total bodily behavior, which in turn places more responsibility on the designer and engineer for the ultimate survival of man.

It is the duty of the interior designer with the architect and environmental engineer to produce an environment acceptable to the human body with the least amount of stress placed on the body's heat-compensation mechanism. The ultimate in terms of comfort which might well be called a zone of thermal neutrality.

The United States "comfort zone" operates between 69-80 degrees Fahrenheit; and in the tropics between 74-85 degrees Fahrenheit with

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[11]James D. Hardy, Thermal Effects of Solar Radiations in Man, (New Haven, Conn.: Yale University, Report Building Research Institute, 1962.), pp. 19.

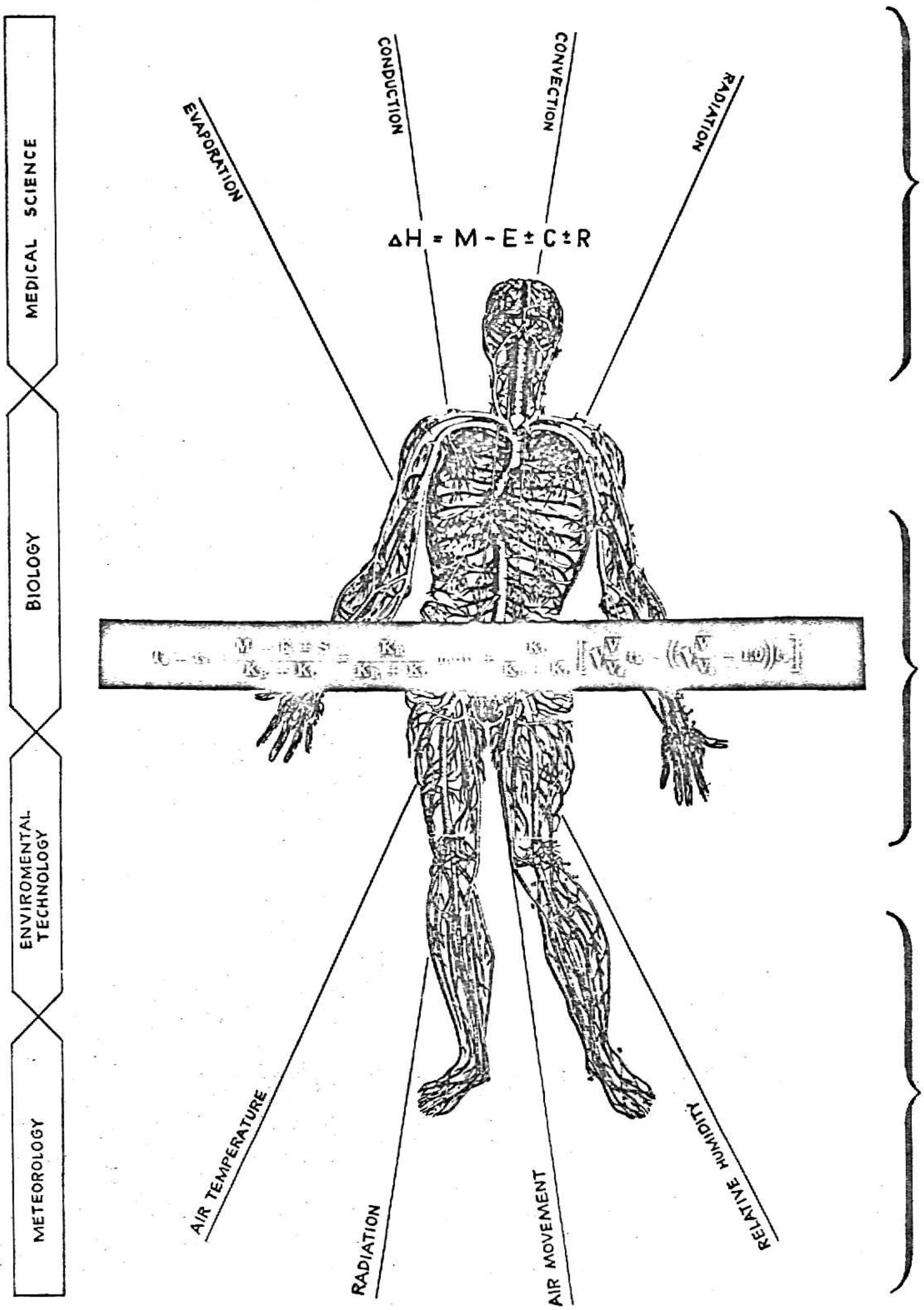
relative humidity between 30-70 percent. The summer "comfort line" should be elevated about 3/4 degree Fahrenheit for every five degrees latitude change toward the lower latitudes in order to apply to climatic regions other than approximately 40 degrees latitude, at the lower edge of the range. The upper range may be raised proportionately, but not above 85 degrees Fahrenheit.

Any comfort zone will differ with the individual, types of clothing, and nature of the activity, the sex, the age of the person, and the acclimation according to the geographical locations elevating the thermal requirements. Obviously, there are only flexible boundaries for the "comfort zone".

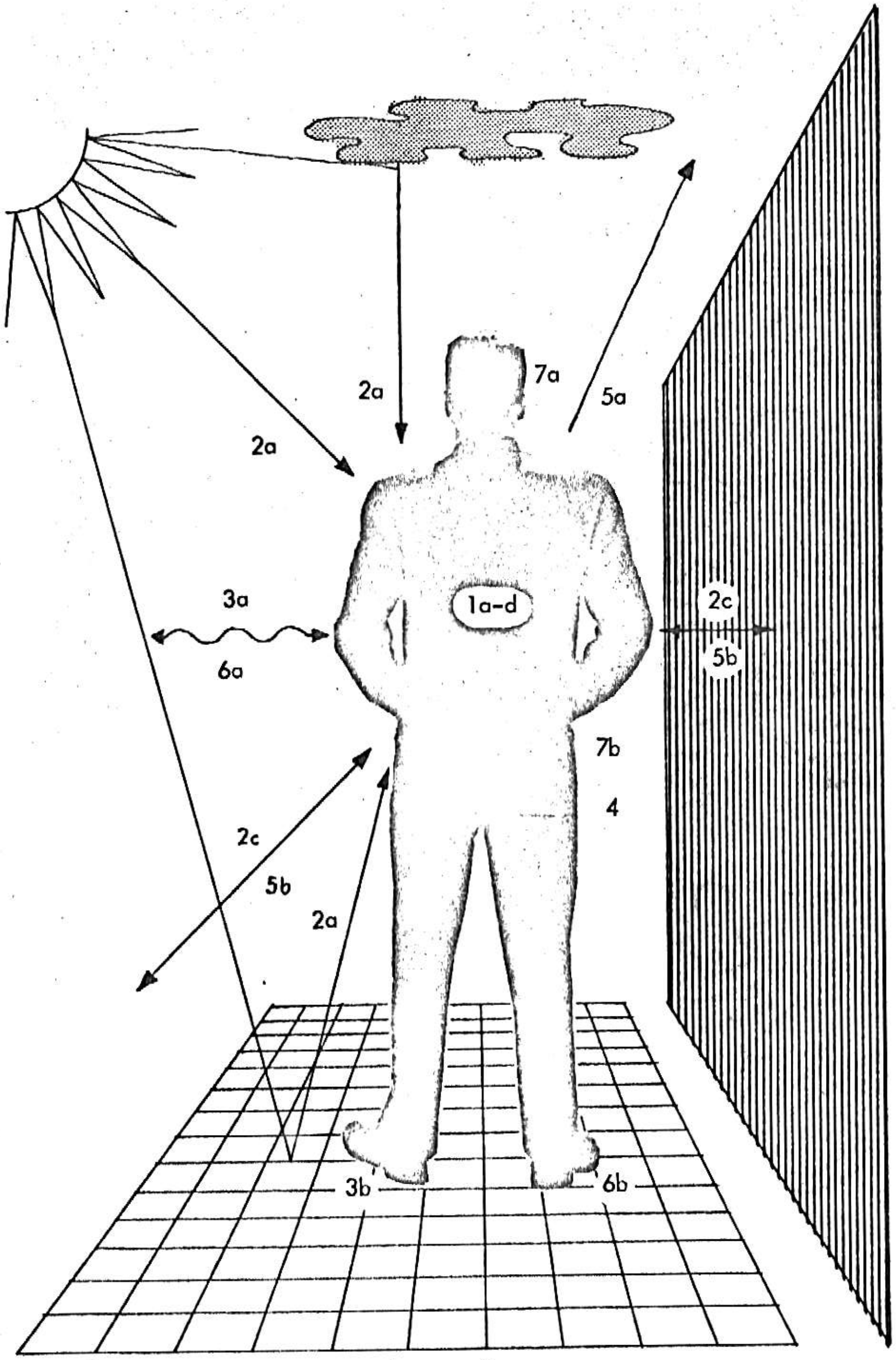
It is possible to estimate the balance of the natural forces that can be utilized in a given building only when the total climatic elements and bioclimatic needs of a definite site are analyzed. The positive elements--sun radiation for cold periods, shade for hot months, ventilation at high humidity cycles, all can and must be considered in relation to the specific occupant needs.

Natural stresses are usually much too heavy for a total structure on an ideal site to be totally within the comfort range. As nearly as is technologically capable, the structure must be as near to the physiological comfort requirements to be called "climate balanced" and within the "comfort zone". Figure 36.15 indicates the relation of human body to the climatic elements as shown on page 11. Figure 37.16 shows the heat exchange between man and his surroundings as shown on page 12.

Data confirm the life expectancy increases as the technological level rises because of more effective control over our own environment.



36. Relation of human body to the climatic elements.



37. Heat exchange between man and surroundings.

GAINS

1. Heat produced by:
   a) Basal processes
   b) Activity
   c) Digestive, etc. processes
   d) Muscle tensing and shivering in response to cold
2. Absorption of radiant energy:
   a) From sun directly or reflected
   b) From glowing radiators
   c) From non-glowing hot objects
3. Heat conduction toward the body:
   a) From air above skin temperature
   b) By contact with hotter objects
4. Condensation of atmospheric moisture (occasional)

LOSSES

5. Outward radiation:
   a) To "sky"
   b) To colder surroundings
6. Heat conduction away from the body:
   a) To air below skin temperature (hastened by air movement-convection)
   b) By contact with colder objects
7. Evaporation:
   a) From respiratory tract
   b) From skin

Life expectancy in the United States increased from 66 to 70 years of age between 1940 and 1960. The United States and Western Europe with high technological levels have one-half the genetic potential; meanwhile in parts of Asia where technology is slower the genetic potential is but one-sixth. Thus the immediacy of good design for building is not only obvious but mandatory.

FUNCTION OF BUILDING

The two principal instruments which are able to remove the burden imposed by the natural environment are: clothing which protects a man from the environment, and building which provides space to enclose and operate as an optimum climate. In society today the building has fallen short of this goal and it is the professional interior designer, the environmental engineer, and the architect who must press for the environmental conditions which are required by those who live and perform their various tasks at peak productivity.[12]

It is the composite of factual research data which points to the art of building as the important essential for the survival of man; finally this realization has dawned and we may direct our aesthetic and technological energies toward a climate controlled building. Hence, we must shift our perspective from the building, its parts and its installed equipment to the environmental condition created by them.

Obvious variations in housing forms developed by groups of similar ethnic background as they encountered the great diversity of climatic regions. However, types of housing, building elements, and designs all too frequently are used today in totally different environments with

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[12]Benjamin Handler, "Needed Research on the Effect of Buildings on Human Behavior, Fall, 1960, Publication No. 910, Building Research Institute Report, Publication No. 1007, p. 7.

little or no relevance to their original climatic site or to their effect on human comfort. Even less consideration is given to the performance of materials in the new location. To cite specific examples, the Cape Cod designs used in the midwest are unsuited to the particular climatic conditions and is merely a transplant by a migrant population, not a true regional expression.[13]

Many are the external pressures placed on the home builder by our culture, social status, and environment simply creating mediocrity and uniformity in house planning. So it is the sub-relationships such as: house-climate, house-man, house-activities, house-topography, to mention a few, which need top priority for the "comfort-zoned" house.[14]

The physical environment is made up of many elements in a complex relationship to each other. Constituents of the environment include: light, sound, climate, space, and the animate. The constituents must function together to succeed as a shelter in the "comfort zone", wherein the energies of man are freed for optimum productivity. Modern building acts as a selective filter which takes the load of the natural environments off man's body and frees his energies for social creativity. The environmental effects, those which act directly and immediately upon the body, and which can be directly and immediately modified by the building, are illustrated in Fitch's diagram 38.17 on the following page, page 15.

"A knowledge of climate is a tool, it is not a science; of itself it leads nowhere, and cannot be a single determinant of design. A

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[13]Victor Olgyay, Design With Climate, (Princeton, N.J.: Princeton University Press, 1963.)

[14]Robert Woods Kennedy, The House, and the Art Of Its Design, (N. Y.: Reinhold Publishing Company, 1953.), p. 477.

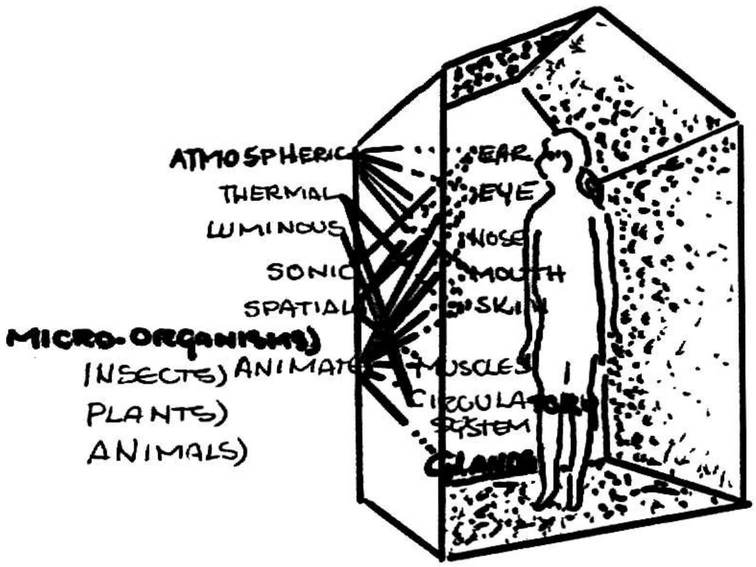

Figure 38.17 -- Modern building acts as a selective filter which takes the load of the natural environments off man's body and frees his energies for social creativity.

knowledge of structure is a tool; it is not engineering; of itself it leads nowhere; and it cannot be a single determinant of design. For the culturally and emotionally broad person, tools and techniques can never be satisfactory ends in themselves."[15]

The focus of building design concepts by the interior designer, the architect, and the environmental engineer is to produce an optimum climate with minimal stress upon the heat compensation mechanism of the human body. The ultimate aim is for man to realize the full potential of his genetic heritage.

A climate-balanced house must be approached with a systematic procedure operating between the borderlines of several fields of knowledge. Richard J. Neutra writes: "For the planning of the future, other arts and sciences, and more than one or two will be needed....the task of constructing many things that make up a human environment...cannot be accomplished well without the use of current and available scientific knowledge...Systematic biological investigation, when carefully correlated with organized policies of design, will rebound to the benefit of a broader human consumership."[16]

DESIGN AND SOLAR EFFECTS ON ARCHITECTURE

The importance of the heat from the sun will vary according to regions and seasons. An optimum orientation for a given site would give maximum radiation in the underheated periods and simultaneously reduce insulation to a minimum in the overheated period. Such an approach to orientation shows that air temperature and solar radiation act together

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[15]Richard J. Neutra, Survival Through Design, (Oxford University Press: New York, 1955.)

[16]Olgyay, op. cit., p. 10

to produce one sensation of heat in the human body. For the greatest utilization of the rays of the sun, their thermal impacts must be considered in conjunction with heat convection, and the total effect measured by its ability to maintain temperature levels near the "comfort zone".

Thus, in planning and designing, an important factor in any solution to optimum conditions for the human body should incorporate the information of occupancy usage times for specific rooms and this factor should be considered in the evaluation of orientation. A table composed by Jeffrey E. Aronin, as shown on page 18, suggests sun orientations for various rooms in residential buildings above the thirty-five degree latitude.[17]

The basic design considerations for buildings are of greatest importance and should include shading devices which are available. Careful planning includes shading effects of trees and vegetation, the mechanical cooling and shading devices in collaboration with radiation, reflected surfaces surrounding the design, air and wind movements, and the specific orientation on the particular geographical location. The entire arrangement of the layout will determine the orientation of the elevations. The size and distribution of the openings, which determine the heat transmission of the elevations, must be considered as well. The proper design of the shading device should be incorporated in the cost and resulting economy only in so far as they all work efficiently.

Research confirms the following observations in "basic forms" of houses: the square house is not the optimum for any location, however, shapes elongated on the north-south axis work both in winter and

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[17]Jeffrey E. Aronin, Climate & Architecture, (New York: Reinhold Publishing Col, 1953.), p. 94-99.

SUGGESTED SUN ORIENTATION FOR ROOMS

	N	NE	E	SE	S	SW	W	NW
Bedrooms	x	x	x	x	x	x		
Living				x	x	x	x	
Dining			x	x	x	x	x	
Kitchen			x	x	x	x	x	
Library	x	x						x
Laundry	x	x						x
Play				x	x	x	x	
Drying Yard				x	x	x	x	
Bathroom	x	x	x	x	x	x	x	x
Utility	x	x						x
Garage	x	x	x	x	x	x	x	x
Workshop	x	x						x
Terraces			x	x	x	x	x	
Sun Porch				x	x	x	x	

Illustration 39.18 Olgyay

summer with less efficiency than the square one. The optimum lies in every case in a form elongated somewhere along the east-west direction. The optimum shape is defined as the one which has the minimum heat gain in summer and the minimum heat loss in winter. Obviously, the thermal forces may be expressed in architectural terms and will vary somewhat with the region.

The temperate region has a temperature range which permits more flexible plans to materialize, still the east-west elongation is most desirable.[18]

We recognize the solar effects on architectural design which determine the environmental relationships and internal function in terms of orientation, bioclimatic evaluation, and use mechanical devices for climate control only to correct problems which fall outside the natural possibilities for climate control. The ultimate aim of the designer is the development of a nearly thermostable state in all buildings with optimum health and the least cost to the builder-owner with an aesthetic quality of the highest caliber.

SUMMARY

The entire history of shelter engineering reveals an unremitting effort by mankind to provide itself with an indoor climate that would reproduce as nearly as possible the climate to which man is best adapted, i.e., the climate of his place of origin. The art of building is of vast importance and essential to the survival of man and for him to realize his life potential.

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[18]Olgyay, op. cit., p. 89-90.

James Marston Fitch points out, "the layman must judge building as he would any other tool - by its performance; and the criterion for judging building performance must necessarily be health...and social well-being. Does the building regulate the commerce between his body and its environment so as to promote optimum health? And, from the standpoint of society as a whole, do its buildings provide (that range of specific) interior climates which will guarantee maximum productivity to all its operations and processes?"[19]

The interior designer has the vast range of technical developments to control and evolve a nearly thermal stable state, producing the optimum in a physiological and aesthetic environment. The designer must act as the catalyst which is able to control the seasonal variables in order to hold stress to a minimum thus releasing man's potentiality for higher productivity, improved personal motivation and greater social interaction.

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[19]James Marston Fitch, American Building, (Boston: Houghton Mifflin Co., 1924).

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ABSTRACT

The entire history of shelter engineering reveals an unremitting effort by mankind to provide an indoor climate that would reproduce as nearly as possible the climate to which man is best adapted, i.e., the climate of his place of origin. The art of building is of great importance for the survival of man and for him to realize his life potential.

Man's energy and health depend in large measure on the direct effects of his environment. It is a common observation to note that on some days atmospheric conditions stimulate and invigorate our activities, while at other times they depress the physical and mental effort. Conclusive evidence reveals that where excessive heat or cold prevails, energy is diminished by the biological strain of adaptation to the extreme condition.

The first of two methods used for the calculation of climatic effects describes the negative effects of climate on man, expressed as stress, pain, disease, and death. The second method defines the conditions in which productivity, health, and mental and physical energy of man are at their highest efficiency. Both approaches may be combined to show coinciding and complementary relationships in defining desirable or disagreeable atmospheric and thermal conditions.

In terms of architectural design this means that the planning and structure of a building should utilize natural possibilities to improve conditions without the aid of mechanical apparatus. Simply, the tangible terms of the problem are: any heat energy captured in underheated periods will reduce heating costs; any quantity of heat kept from reaching the interior in overheated times will lessen the expenditure for cooling.

The role of the interior designer is that of correlation of the report and findings of the climate data and evaluations evolved by the climatologist. Too, the interior designer combines this factual technology with calculations of shading, radiation, winds, materials and variations of other factors such as precipitation, evaporation, humidity, etc. and depends on the architect and engineer to produce findings for architectural examples with practical considerations, and then makes the feasible application which will develop controls for a nearly stable thermal state with the optimum in physiological and aesthetic well-being.