I. GENERAL INTRODUCTION

THE EARTH AND LIFE

The full spectrum of earth's arena ranges from the rigor of the cold blues to the oppression of the torrid reds, and only the restful hues near green are associated with life. The bluish-white of icecaps in the polar regions blends into a brownish-green where vegetation makes its first stand in the tundra. This gives way to the dark green coniferous belt of the cold zone, which merges southward with the broad-leaved deciduous trees of the fertile temperate region. Further down, the warm middle latitudes are marked with the sparsely inhabited yellowish-reds of the desert areas, and the tones finally deepen into the lush green of the permanent verdure around the equatorial belt.

Surrounded by oceans, the great land masses are relieved by heights and depths of mountains, plains, and plateaus, and enlivened by veins of rivers and networks of streams and lakes. On and beneath the surface lie the meager or abundant soils and minerals which make life prosperous or infertile.[1]

There is a discipline, however, imposed on this complexity. The revolution of the globe gives the heartbeat of day and night which regulates the activities and reposes of natural life. The tilted rotation of the earth around the sun sets the rhythm of the seasons, which call to life the dormant vegetation and donate the bounty of harvests. Whether each locale is cool or warm is largely determined by its relative distance from the equator; but the imperative regularity of the sun also sets the pace for the patterns of humidity and wind that sweep across the earth.

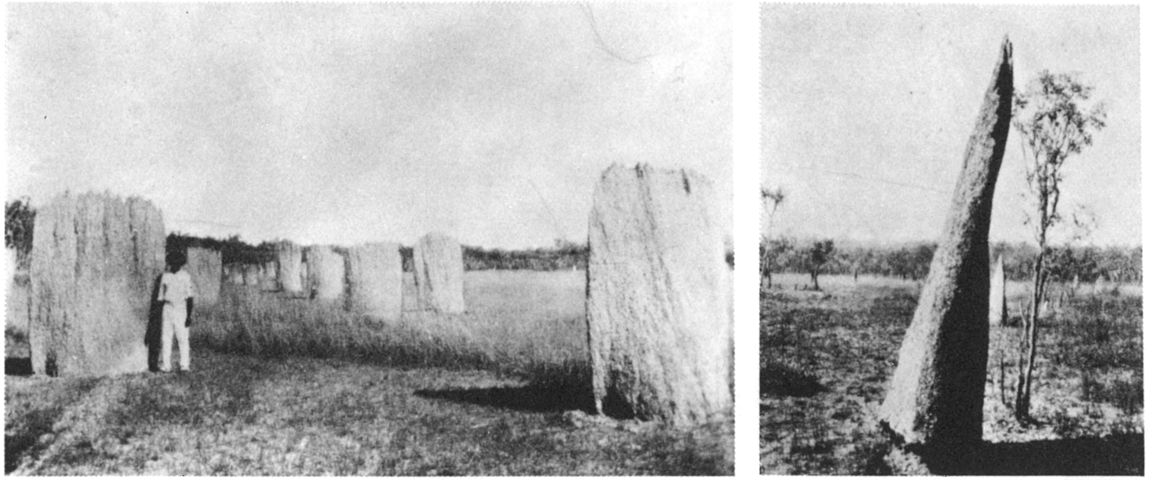
The features of the physical environment are blanketed by a vast ocean of air, whose tides carry climatic elements to all parts of the earth and are in turn modulated by them. Climate not only plays a great part in the composition of soils, but strongly affects the character of plants and animals in different regions and—most important from our point of view—man's energy.[2]

As life has arisen through the hidden aspects of natural laws, so for better or worse the rules of nature command that life make a close adjustment to natural background. The setting is impartial; it can be kind or cruel, but all living species must either adapt their physiology, through selection or mutation, or find other defenses against the impacts of environment.

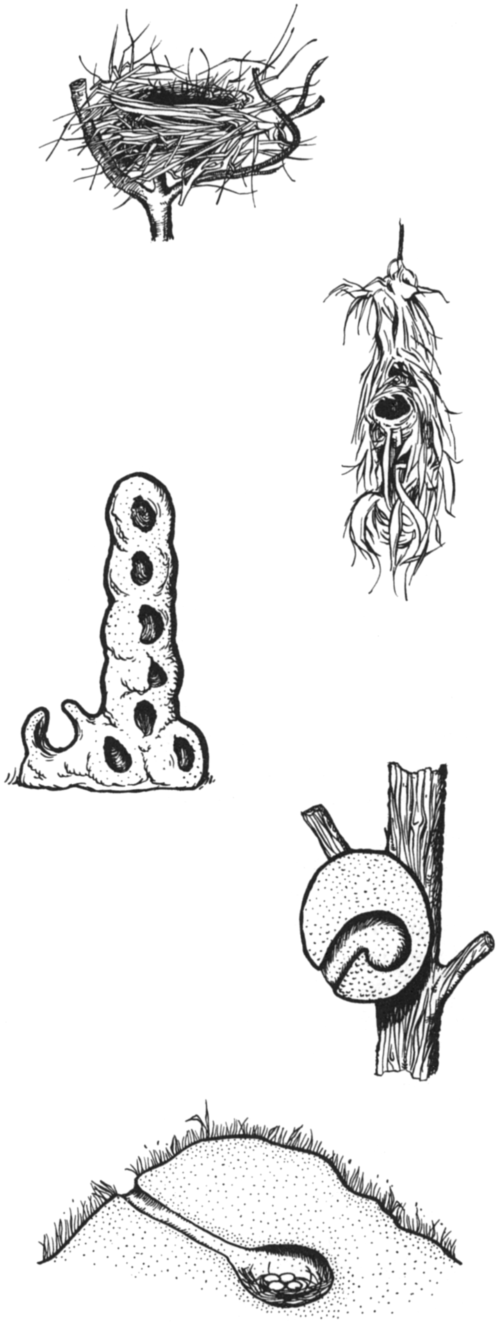
ANIMAL LIFE AND SHELTER

Mankind's physical flexibility and capacity for adaptation are relatively feeble compared to those of many animals, who possess natural defenses against a large range of unfavorable climates. Against the danger of dryness animals have a number of weapons, and to relive the impacts of excessive heat they use heightened transpiration. The bear, in cold weather, can reduce his metabolism through slumber. The bat can survive a change of its body temperature of 60 degrees. The elephant can cool its blood by moving its honeycombed ear. As cold arrives the mink grows a new fur coat. In the hostile territory of the desert many animals reverse their life rhythm, live by night, and tuck away underground at dawn. Some rabbit breeds place their burrows with efficient foresight in relation to water and wind.

Birds can regulate their body insulation by trapping minute air bubbles with their adjustable feathers. When hardship becomes excessive, they seek to change to an environment where food and warmth are more favorable for existence. Birds during their stay do not rely entirely on their ability to adapt, but enlarge this ability with their building habits,



3. East (left) and south views of termites' nests.

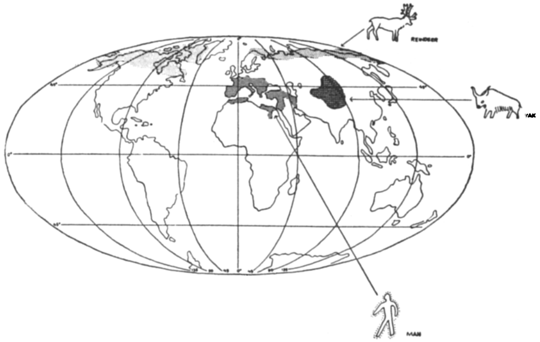


2. Bird nests to react against climatic impacts.

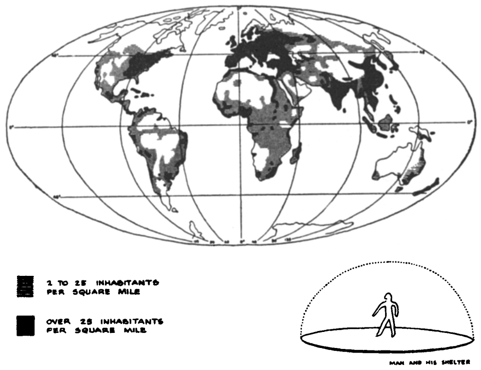
with an innate instinct to cope with their environment. The varied forms and delicate patterns thus produced provide enlightening examples of the intuitive reconciliation of natural forces.

The open nest secures insulating qualities; the hanging nest utilizes the tensile strength of fibers, or grasses, and, pendulum-like, avoids the wind forces. The nest which is massively built from clay and straw prevents the intrusion of the direct sun and rain by its steep entrance. The vertical mud and straw nest is similar to apartment dwellings, where each opening is an individual nest comprised of two chambers. The first serves as an entrance foyer, the second an egg laying and hatching area. This very special form successfully avoids the nearly vertical sun rays, and minimizes the effect of precipitation. The mass of the earth can effectively relieve extreme temperature differences and secures more stable heat conditions. Each solution is an effort, with a different approach, to cope with some main element of the climatic surroundings.[3]

These individual efforts for shelter are surpassed by the collective building of the insect world. Anthills vary with their surroundings; in temperate regions they are often found on southeast slopes, and elongated on a northeast-southwest axis to catch early morning warmth.[4] But in the tropics, the immense buildings of Hamitermes meridionalis ("compass termites") are blade-shaped and point due north. The east and west exposures help to secure an equable temperature; but, as with most mound-buildings, the large mass of earth stabilizes the caloric range.[5] Their towers are immense, reaching 400 times their body-length (10 mm), which translated into human terms would equal 2400 feet.

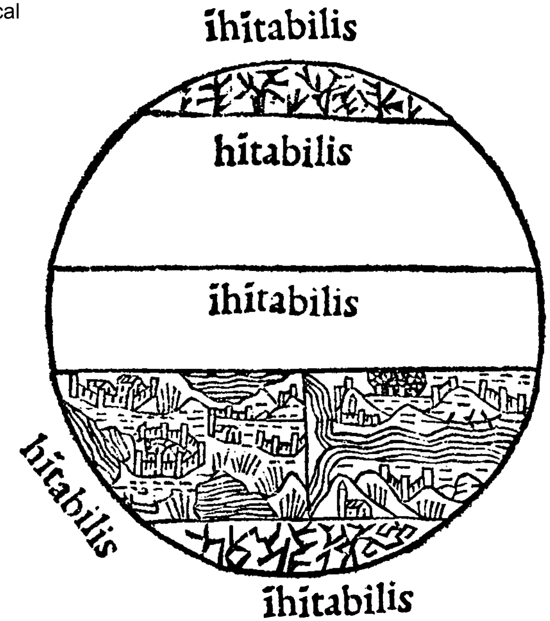


4. Early history habitat of man and animals.



5. Present density of world population.

6. Macrobius's climate zones.



7. Sacrobosco's climate regions.

HUMAN LIFE AND SHELTER

Mankind in the same environments encounters the same stresses as other fauna. From Aristotle to Montesquieu, many scholars believed that climate had pronounced effects on human physiology and temperament. More recently interest has centered on human energy in relation to environment. Ellsworth Huntington has hypothesized that climate ranks with racial inheritance and cultural development as one of the three great factors in determining the conditions of civilization.[6] According to him, man, who can apparently live in any region where he can obtain food, has strictly limited conditions under which his physical and mental energy (and even his moral character) can reach their highest development. He postulates optimum climate conditions for human progress:

1. average temperature ranges from somewhat below 40° F in the coldest months to nearly 70° F in the warmest months;
2. frequent storms or winds, to keep the relative humidity quite high except in hot weather, and provide rain at all seasons;
3. a constant succession of cyclonic storms which bring frequent moderate changes in temperature but are not severe enough to be harmful.

Another contemporary, Julian Huxley, relates human history to climate by comparing the incidence of early civilizations with that of dry and wet epochs.[7] He speculates that the biological and economic effects of the shifts in climatic belts hold the balance for populations. When the belts shift, migrations are caused, which in turn bring not only wars but the fertilizing exchange of ideas necessary for the rapid advance of civilization.

Man's inventiveness enabled him to defy the rigors of his environment with fire for warmth and with furs for clothing. When the weakling among animals substituted Promethean inventiveness for the physical adaptation of other species, the shelter became his most elaborate defense against hostile climates. It enlarged the space of biological equilibrium and secured a favorable milieu for productivity. As the shelter evolved, accumulated experience and ingenuity diversified it to meet the challenges of widely varying climates.

ADAPTATION OF SHELTER TO CLIMATE

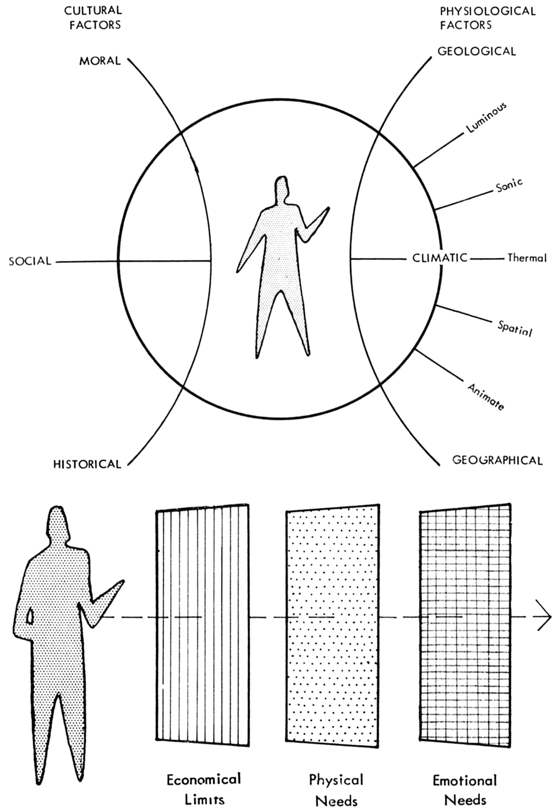
Virgil wrote: "Five zones possess the sky, of which one is ever/red from blazing sun and ever burnt by fire."[8] Sacrobosco, in his *Sphaera Mundi,* projected these five celestial zones on the earth, and agreed that the central one was uninhabitable "because of the fervor of the sun. . . . But those two zones . . . about the poles of the world are uninhabitable because of too great cold, since the sun is far removed from them."[9] Hence, he concluded, only the temperate zones were fit for civilized habitation, and most of the classical world agreed with him.

Nevertheless, the ancients recognized that regional adaptation was an essential principle of architecture. Vitruvius said in *De Architectura:*[10] "For the style of buildings ought manifestly to be different in Egypt and Spain, in Pontus and Rome, and in countries and regions of various characters. For in one part the earth is oppressed by the sun in its course; in another part the earth is far removed from it; in another it is affected by it at a moderate distance."

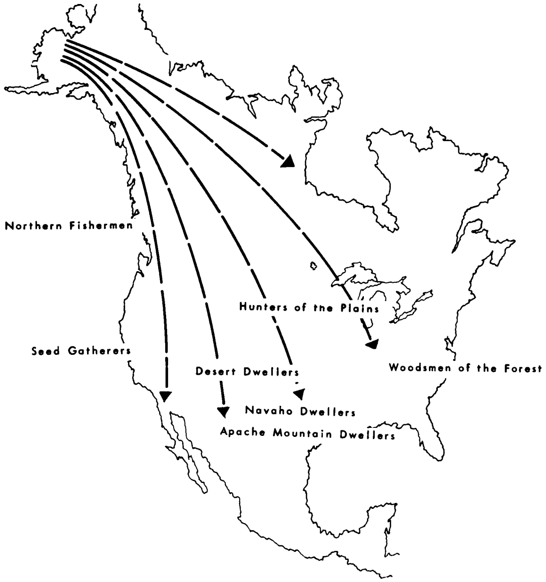
In contemporary architectural thinking there are many approaches to man's physiological, as well as aesthetic, well-being. To treat climate as a primary factor is justifiable only if the thermal environment proves to be one of the influential factors on the architectural expression. Dr. Walter B. Cannon maintained that it is: "The development of a nearly thermostable state in our buildings should be regarded as one of the most valuable advances in the evolution of buildings."

One corroboration of this thesis is apparent when one considers the diverse housing forms developed by groups of similar ethnic background when they encountered widely varying climatic regions. It is generally agreed that the American Indians stemmed from Asia and that the waves of their migration across the Bering Strait established their populations from end to end of North and South America. As they spread throughout North America, the Indians entered into a broad variation of climatic environments, from the cold-cool northern territories to the warm-hot areas of the south, from the dry western areas to the humid parts of the southeast.

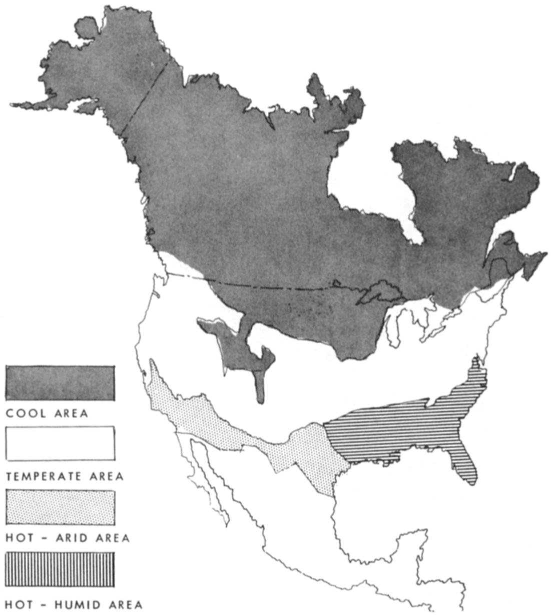
The tribes entering the cold zone encountered extreme cold and relatively scarce fuel. Under these circumstances, the conservation of heat became essential, so their shelters were compact, with a minimum of surface exposure. The Eskimo igloo is a well-known solution to the problem of survival in extreme cold. These low hemispherical shelters deflect the winds and take advantage of the insulating value of the snow that surrounds them. The smooth ice lining which forms on their interior surface is an effective seal against air seepage, and their tunnel exits are oriented away from



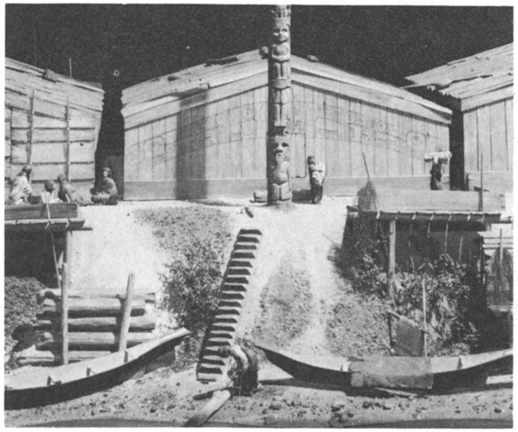
8-9. Factors influencing architectural expression.



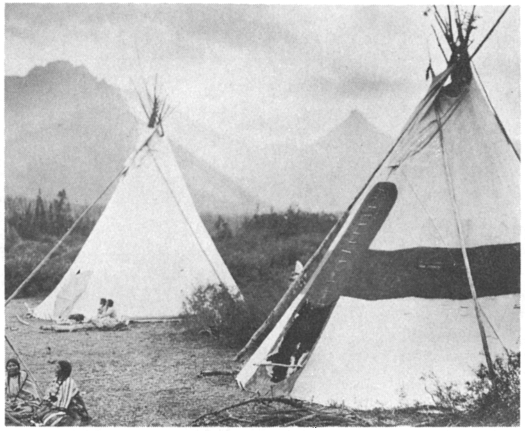
10. Diffusion of migrating Indian groups.



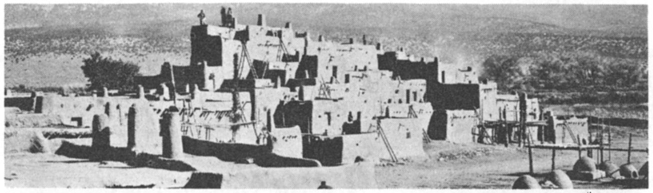
11. Regional climate zones of the North American continent.



12. Cool Area.



13. Temperate Area.



14. Hot-Arid area.

15. Hot-Humid area.

the prevailing winds to reduce drafts and prevent the escape of warmed air. The heat retention of this type of structure makes it possible to maintain a temperature of 60° F inside when the exterior temperature is −50° F. Such structures may be heated by a small lamp supplemented by body heat.

The Pacific Coast tribes of British Columbia encountered a less extreme climate, although the need for heat conservation remained acute. To meet this demand these Indians adopted a form of communal living, as shown by the structure of the habitations of the Kwakiutl Indians. The homes of these tribes were joined together to reduce the exposed surfaces. The large plank-and-timber shelters were built as double shells, an arrangement that produced an insulating air space and provided an enclosed ambulatory between family units for the snowy winter months. In the summer the outer shell could be removed for ventilation. Further mutual benefit was achieved by the placing of fire pits within individual apartments along a center aisle, thus creating a concentrated heat source. In the Mackenzie Basin, shelters were constructed of bark and timber, covered by low-pitched roofs with long poles anchored to the covering to retain the snow as an insulating blanket.

The temperate area, offering a naturally favorable climate, made fewer thermal demands on its inhabitants, and there is a corresponding diversity and freedom in the structures of these peoples. Unlike the communal groupings of the Pacific Coast, the villages of the eastern woodsmen and plains dwellers were freely organized and spread out, with peripheral units merging into the surrounding landscape. The typical dwelling unit of these tribes was the wigwam, a conical structure of poles covered by skin, which effectively shed wind and rain and was easily heated from a central source. It could be readily transported, an essential to migration.

In contrast, the hot-arid zone made extreme demands on the constructors of tribal dwellings. Characterized by excessive heat and glaring sun, this area requires that the shelter be designed to reduce heat impacts and provide shade. The southwestern tribes, like those far north of them, often built communal structures for mutual protection—in this case from the heat. Structures such as the pueblo of San Juan were constructed of massive adobe roofs and walls, which have good insulative value and the capacity to delay heat impacts for long hours, thus reducing the daily heat peaks. They also used very small windows. By packing buildings together, the amount of exposed surface was reduced. Pueblo structures of this type usually extend on an east-west axis, thereby reducing morning and afternoon heat impacts on the two end walls in summer and receiving a maximum amount of south sun in the winter months when its heat is welcome.

The hot-humid area, on the other hand, presented two major problems to its inhabitants: the avoidance of excessive solar radiation and the evaporation of moisture by breezes. To cope with these problems, the southern tribes built their villages to allow free air movement, and the scattered individual units were mixed into the shade of surrounding flora. The Seminoles raised large gable roofs covered with grass to insulate against the sun and throw large areas of shadow over the dwellings, which had no walls. The steep angle and extensive overhang of these roofs protected against rainfall, and the floors were elevated to keep them dry and to allow air circulation underneath.

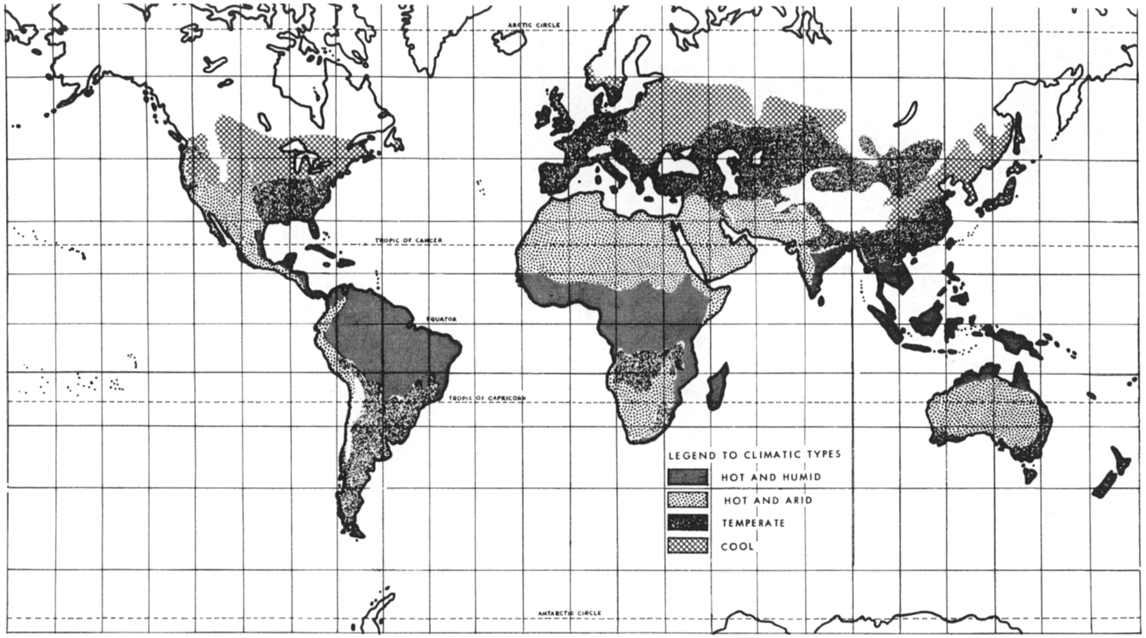
As may be seen from these basic building forms used by the North American Indians in various regions, these people possessed a remarkable ability to adapt their dwellings to their particular environmental difficulties. An awareness of climate was integrated with innate craftsmanship to solve problems of comfort and protection. The results were building expressions of true regional character.

SIMILARITIES AROUND THE WORLD

Although a global evaluation is beyond the scope of this book, the zones of climate can be traced around the earth. There are many systems for classifying them, but W. Köppen's is generally accepted. Using the relation of climate to vegetation as a criterion, he determined five basic climate zones: tropical-rainy, dry, warm-temperate, cool-snow-forest, and polar.[11] Some authors, such as Trewartha, offered modifications of these divisions based on the isotherms of the coldest months.[12] Since the detailed classifications are not directly applicable to housing, a simplified map based on Köppen's system is presented here.

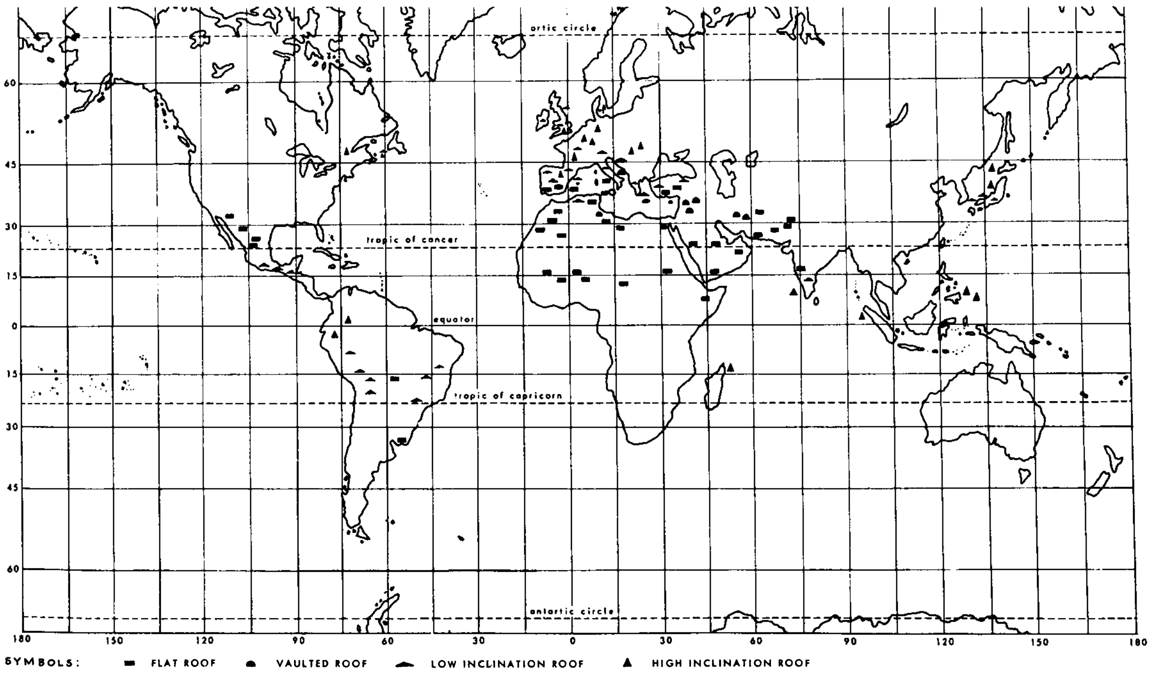
For the architect's use "homoclimate," or human need, is the determining factor. That a thermostable condition has for centuries been the main goal of builders is corroborated by Jean Dollfus' sampling of characteristic dwellings around the world. He finds that building styles are defined less by national frontiers than by climate zones. Allowing for some variation in local taste and tradition, the general forms of native habitation are born of the environment.

In his first category, the great equatorial forest and tropical savannahs (Africa, Monsoon Asia, Australia, Polynesia, Amazon), he emphasizes that the roof is more essential than the



16. Climatic zones.

17. Typical occurrence of indigenous roof types.



walls, which can be omitted altogether. Throughout this zone we find "timber skeletons, wood construction, branches, woven sticks, lath, thatch, and verdure."[13]

In cold northern forest and mountain regions, from the northwestern U.S. through Scandinavia and to the Himalayas, Dollfus groups houses of heavy timber with beam construction. These have low-pitched shingle or wooden roofs that allow dry snow to act as insulation.

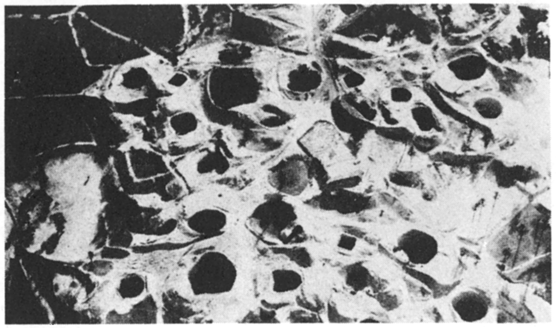
In an intermediate zone, the walls consist of adobe construction covered with a thatched roof (West Africa, Andes), and here, too, are areas where nomads live in tents of felt or skins. Near to these is a great band of habitations (Mauretania, Gobi, Mexico) where the walls have a more important protecting role than the roof—in the arid zone of steppes and deserts. Here "the walls are built of stone, dried or baked clays supporting a flat roof of earth."

Between the bands of extreme climates, Dollfus divides the northern temperate zone on a line 45° N in Europe and 30° N in America. South of this, the walls constitute the principle element of the house and are built of bricks or stone and covered with slightly sloping roofs of semi-cylindrical tile (Mediterranean, Latin American, and Chinese regions). North of the line are some stone walls and a large amount of timber construction with the panels filled with mud, bricks or rough stone, or even paper. These house types have tall roofs, with an angle of 45° or more, covered with thatch or shingles.

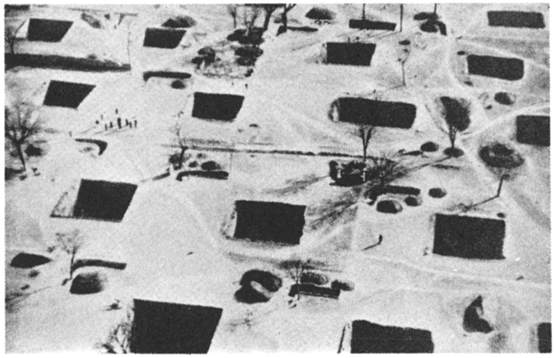
Another significant factor that Dollfus notes: "The proportion of solid surfaces to openings in the exterior façades depends as much on popular psychology as on the climate and the materials used. In the zones of extreme temperature, for inverse reasons to safeguard against the sun or the cold, the walls are pierced only in a small proportion of their surface. And in general, rural interiors are much more stingy of air and light than those of the towns. . . . In northwest Europe the shade of urban streets sets the demand for more illumination, and it is in those gabled houses that windows attain their greatest development."[14]

It is evident that the roof is a determining element in the general form and appearance of regional house types. There is a marked correlation between zones of the climate map and the locales in which roof types commonly occur. Flat roofs appear in the hot zones, vaulted roofs are found in dry areas, and inclined roofs are found in the temperate climates with consistently dry summers. House types with higher roofs are used in the wet-temperate and cooler territories.

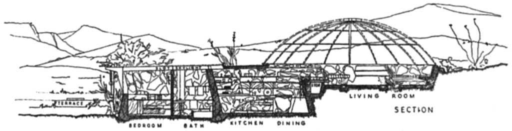
In the special case of the dome and vaulted roofs, the rounded form has been attributed to ancient philosophical motives.[15] It has also been suggested that it was easy to mold primitive domes with a branching tree as scaffold, or that the form is convenient where large timbers are scarce. But both domes and vaults are most popular in hot-arid regions with clear skies, where the low humidity leads to intense radiation exchange and creates extreme temperature variations between night and day. This has an underlying logic, probably discovered through centuries of experience: the envelope of a hemispherical vault is roughly three times the surface of its base, so the radiation of high sun positions is diluted on a rounded surface. This results in lower surface temperatures, which are further reduced by wind cooling. The rounded form is also suited to release the nocturnal outgoing radiation and facilitate nightly cooling. This is especially true in masonry construction, where the heavy building material, through its time lag in conducting heat, secures balanced daily thermal conditions.

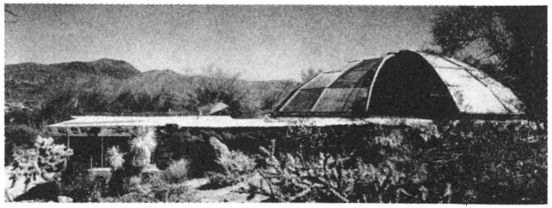


18. Settlement of troglodytes in Tunis.



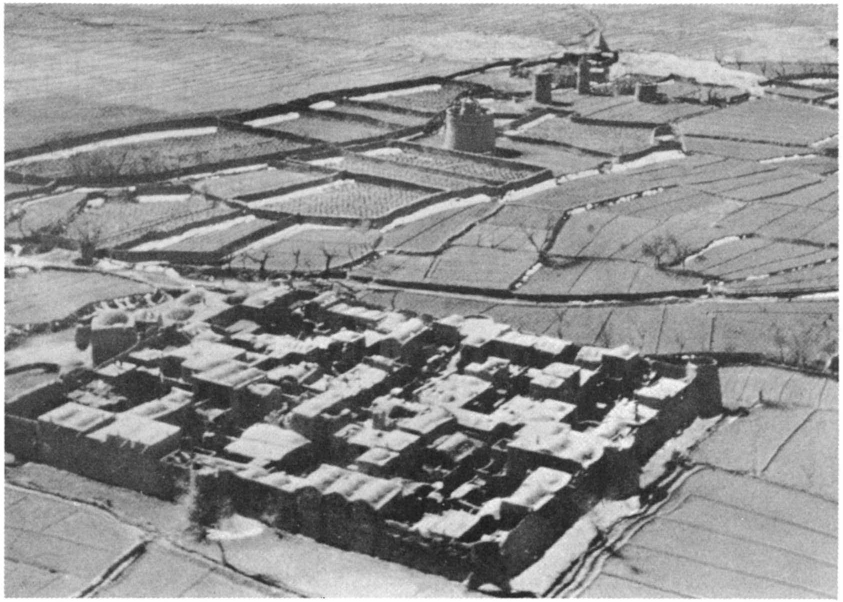
19. Subterranean settlement in China.





20-21. Soleri's house in Arizona.

The importance of capacity insulation in extreme examples, which command a certain respect for their ingenuity, shows how concepts emerged under excessive stresses of similar nature. The habitats far away from each other, but the common denominator is low humidity with intense sun and heat, and they led to an obvious and rational solution in the cave principle. The Tunisian troglodytes of Matmata have their subterranean chambers located around open central wells, which appear on the surface in a complex organic community pattern. The more geometric-minded Chinese of Honan cut their dwellings 30 to 45 feet into the loess and reached them through hook-shaped stairs. Those solutions, however extreme, have their logical reasons. A mass of earth below the surface retains temperatures close to the yearly average, rendering relative warmth in winter and coolness in summer. This principle has its respectable followers today who advocate the Lithosphere house types. A contemporary version of earth-cooled temperature moderation shows how time-proved principles can be integrated and adapted in the light of contemporary knowledge to similar hot-arid regions.



22. Village in Hot-Arid zone.

From examples we find a remarkable correspondence between special architectural features and certain climatic zones. It is more than coincidence that groups of different continents, creeds, and cultures appear to have come independently to similar solutions in their struggle with similar environments, and to have established basic regional characteristics.

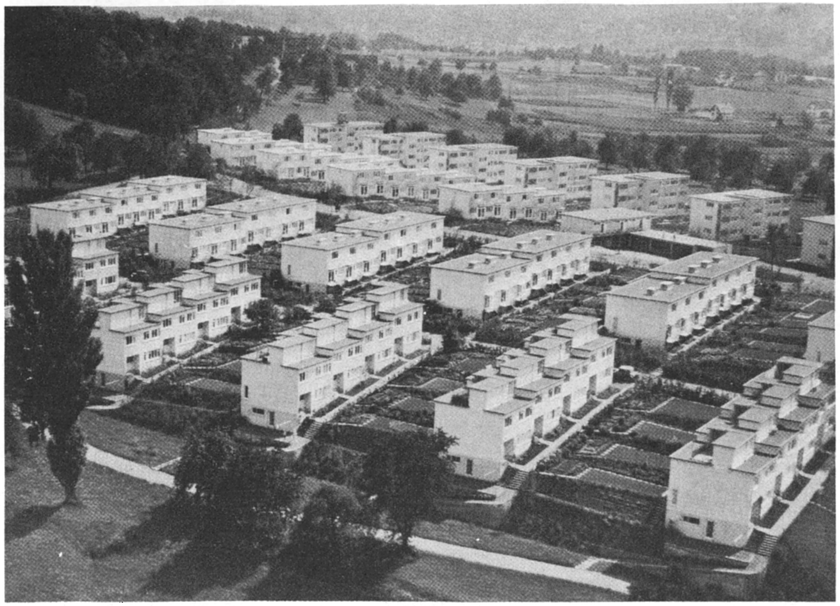
COMMUNITY LAYOUTS AND CLIMATE

The three community units pictured give a first impression that they are as strikingly dissimilar as they are distant from each other, not only in space and time, but in level of living.

A long, close contact with nature evolved solutions such as those of the Iranian village in the Oasis of Veramin, where the village huddles together to leave the least surface to the scorching heat. The geometric minimum of the individual units is echoed in the total layout, bringing an appealing unity, and the closeness yields protection through mass. The thick walls tame and delay the thermal variations. The courtyards are shaded, providing cooling wells and establishing "introvert" dwelling units looking inward from the hostile environment. This distinct order took form through the urgency of biological necessity.

In the tropical Sudan lies a Bari village which displays an entirely different character. In the near-equatorial sky the sun remains high overhead, the temperature varies little, and the hazy firmament is moisture-laden. Both radiation and rain come from above. Therefore the roof is the main element; this is emphasized by the umbrella-like cover thatched in rings. The walls lose their usual role, and the boundary of the house is loosely defined by the shade-giving roof. The winds are welcome, and buildings, like people, are lightly clad. Space can flow easily, and this fluid accessibility accounts for the pavilion-like arrangements in a spontaneous organic freedom.

23. Village in Hot-Humid zone.



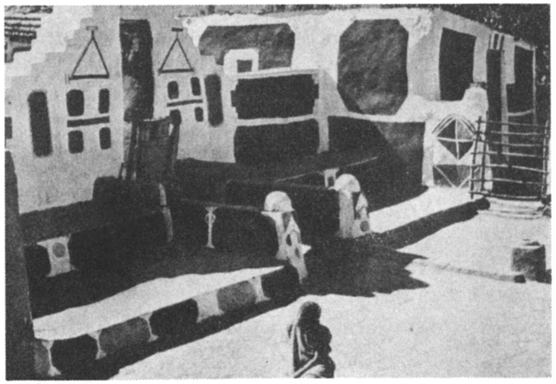
24. Housing in Temperate area.

The community of Zurich lies in the cool-temperate climate of Switzerland. Here the natural setting, however friendly, has variations that call for a carefully balanced building to act as a sun trap in the winter and a shaded shelter in the hot days, to fulfill a dual role as a summer jacket and a warm overcoat. In this climate range evolved the housing types of western civilization, with their large windows and extroverted easy communication with the natural surroundings.

Despite the diversity of these contrasting community layouts, they have something in common: all of them have marked regional characteristics, strong statements that are clear answers to their respective climatic demands.

REGIONAL CHARACTER

The spread of populations and modern communications have accelerated the age-old interchange of ideas and technological effects. We must realize, however, that the wide dissemination of Western forms should proceed with caution. These forms evolved from the challenge of cool climates, and can pose grave problems when adopted as undigested and inappropriate symbols of cultural progress. Valuable insights into the use of native materials and genuinely original building elements may be lost with the discarding of inherited traditions. Of course these must be carefully sifted from the beliefs and customs of the region. Built-in superstitions exist, for example, in Malaya, where a trench before a house means bad luck; a room can not have views on opposite sides, which would be highly desirable for cross-ventilation; and an entrance cannot be oriented so that a visitor's shadow would fall across the threshold. In other areas the few windows have to be closed at night against evil spirits.



25. Expression of strength and sincere beauty of an African village.

26. Elegance in regional expression at the Hot-Humid island climates.

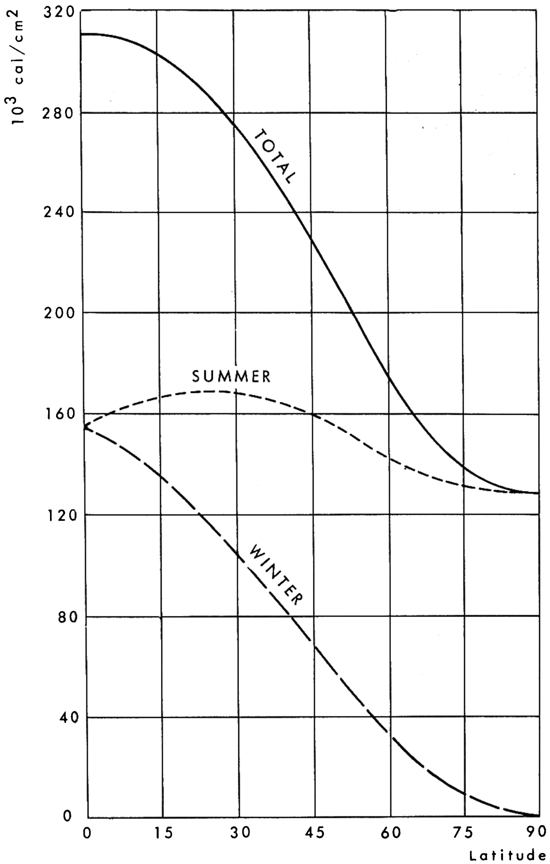
On the other hand, it might be well to appraise our own practices in the light of global reevaluation. In the United States, despite the great variety of climatic conditions, building design often reflects a heedless uniformity. Housing types and building elements and designs are too often used in diverse environments with little or no relevance to their effect on human comfort, or even to the performance of materials. Undoubtedly they do not reflect the regional character, but are transplanted by a migrant population. Many causes of this wasteful uniformity can be cited, but perhaps the most decisive impact came from the technological advances in house heating and house cooling.

Walter Gropius, considering regional expression, writes ". . . true regional character cannot be found through a sentimental or imitative approach by incorporating either old emblems or the newest local fashions which disappear as fast as they appear. But if you take . . . the basic difference imposed on architectural design by the climatic conditions . . . diversity of expression can result . . . if the architect will use the utterly contrasting indoor-outdoor relations . . . as focus for design conception."[16]

TO FIND A METHOD

The desirable procedure would be to work with, not against, the forces of nature and to make use of their potentialities to create better living conditions. The structure which in a given environmental setting reduces undesirable stresses, and at the same time utilizes all natural resources favorable to human comfort, may be called "climate balanced." Perfect balance can scarcely be achieved except under exceptional environmental circumstances. But it is possible to achieve a house of great comfort at lowered cost through reduction of mechanical conditioning. We will do well to study the broad climate layout, then apply the findings, through a specific region, to a specific structure. And one must be ever alert to regional variations.

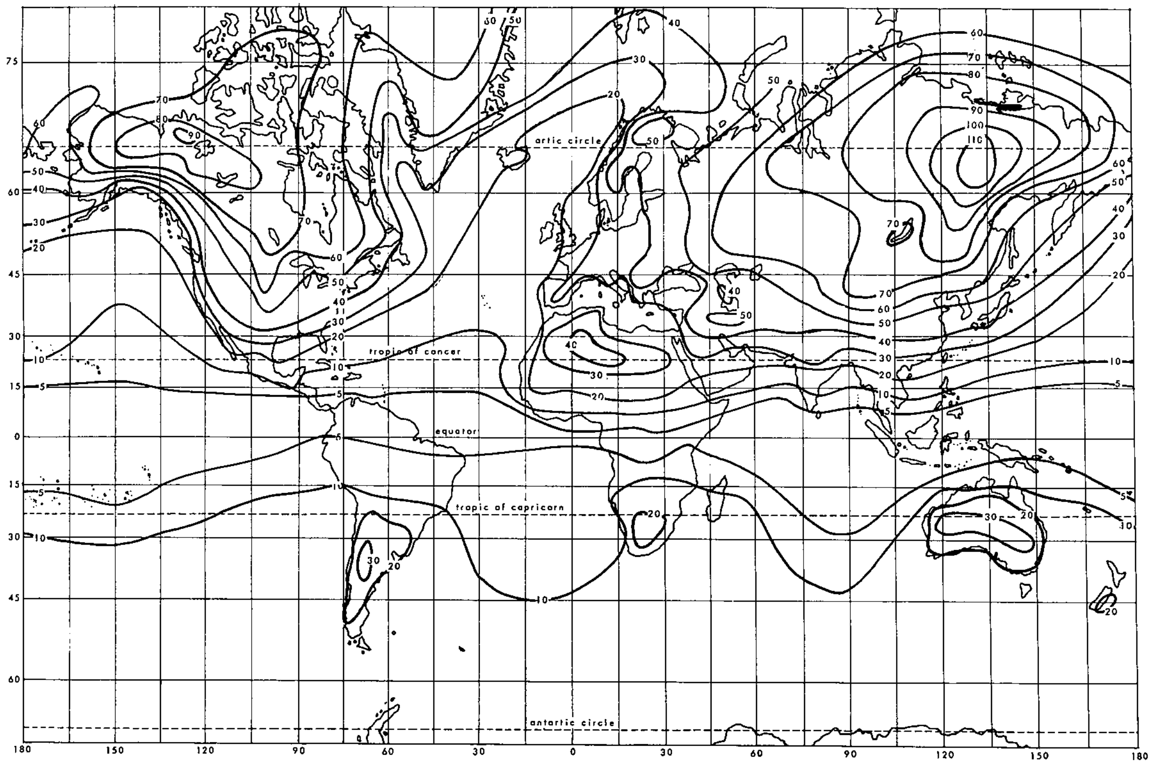
A systematic approach to climate-balanced conditions poses an intricate problem since the procedure itself exists between the borderlines of several fields of knowledge. One can readily identify two of these fields: climatology and architecture, which contain the beginning and end of the problem. By combining these two fields, considerations for building design can be deduced. As Neutra writes:[17] "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



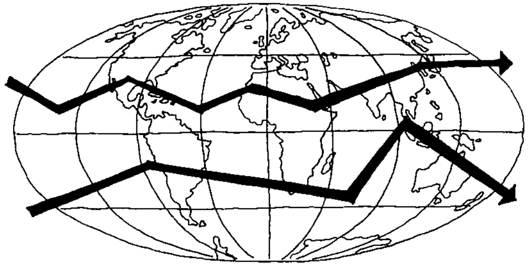
27. Radiation received at the ground in absence of the atmosphere at various latitudes.

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."

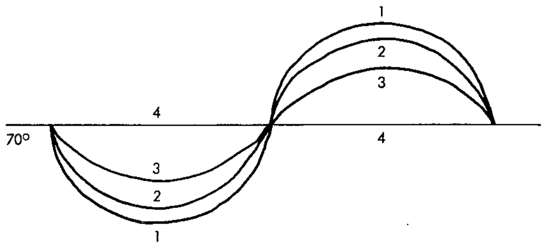
A universally applicable method for architectural climate control must be based on broader foundations than have been used heretofore, and they must be accompanied by more careful analysis of a specific area. To adopt such a process one must seek out the intermediate steps.



28. Mean annual temperature range.



29. Horizontal correlation of climate influences.



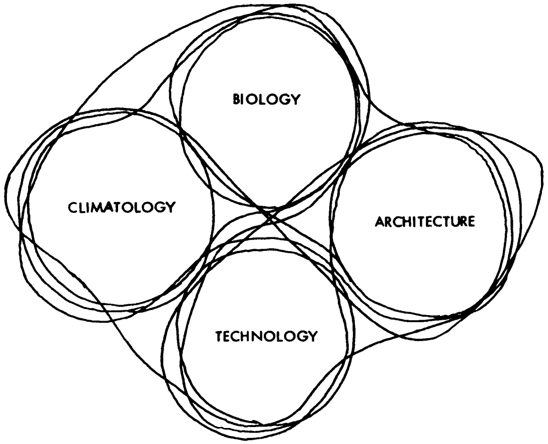
30. Flattening the temperature curve from environmental conditions (1) by microclimatology (2) and climate balance of the structure (3) to mechanical heating or cooling (4).

The process of building a climate-balanced house can be divided into four steps, of which the last is architectural expression. Architectural expression must be preceded by study of the variables in climate, biology, and technology.

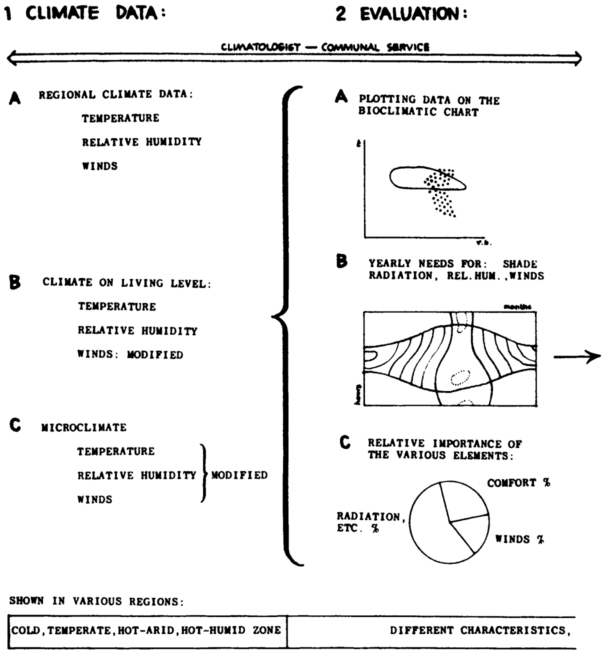
The first step toward environmental adjustment is a survey of climatic elements at a given location. However, each element has a different impact and presents a different problem. Since man is the fundamental measure in architecture and the shelter is designed to fulfill his biological needs, the second step is to evaluate each climate impact in physiological terms. As a third step the technological solutions must be applied to each climate-comfort problem. At the final stage these solutions should be combined, according to their importance, in architectural unity. The sequence for this interplay of variables is Climate → Biology → Technology → Architecture, and in general this book will follow that sequence.

In particular, the steps of the method comprise:

1. Climate Data of a specific region should be analyzed with the yearly characteristics of their constituent elements, such as temperature, relative humidity, radiation, and wind effects. The data, if necessary, should be adapted to the living level. And the modified effects of the microclimatic conditions should be considered.
2. Biological Evaluation should be based on human sensations. Plotting the climate data on the bioclimatic chart at regular intervals will show a "diagnosis" of the region with the relative importance of the various climatic elements. The result of the above process can be tabulated on a yearly timetable, from which measures needed to restore comfort conditions can be obtained for any date.

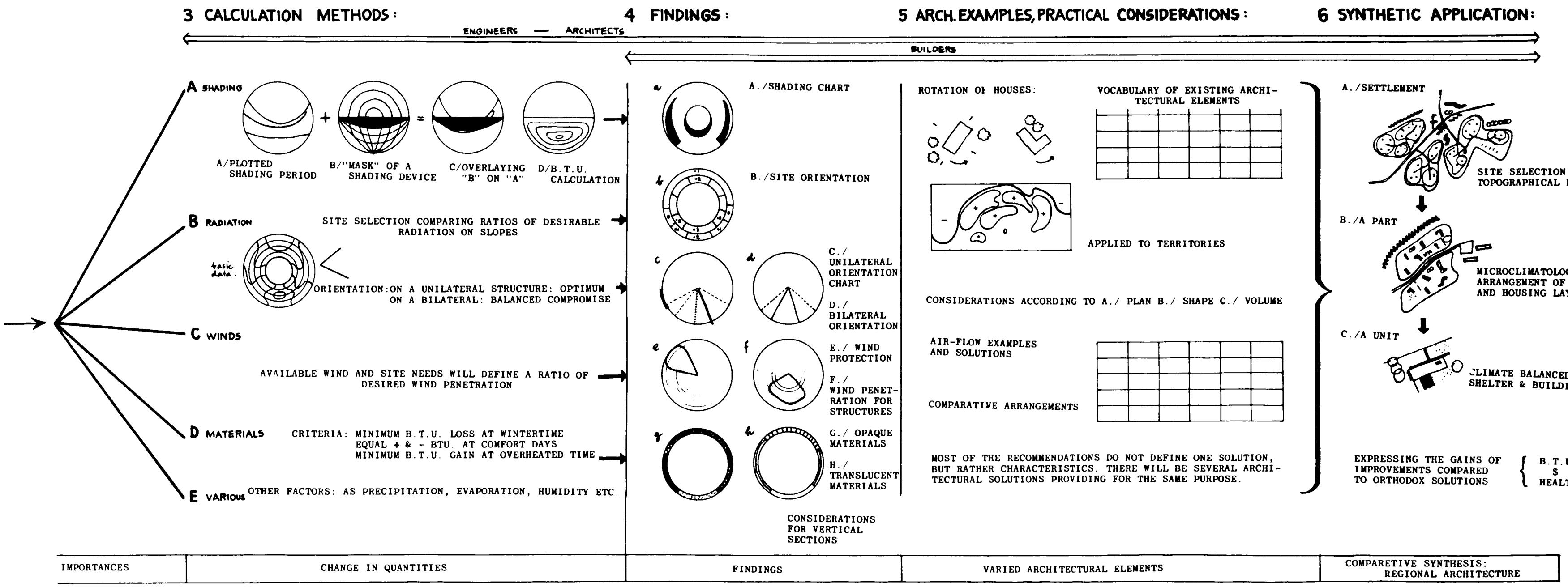


31. Interlocking fields of climate balance.



32. Method of climate interpretation in housing.

3. Technological Solutions may be sought, after the requirements are stated, to intercept the adverse and utilize the advantageous impacts at the right time and in adequate amount. This necessary function of a balanced shelter should be analyzed by *calculative methods:*
   - A. In *site selection* most of the factors are variable. In general, sites which show better characteristics in the winter-summer relationship are more livable.
   - B. In *orientation* the sun's heat is decisive both positively (in cold periods) and negatively (in hot periods). A balance can be found between the "underheated period," when we seek radiation, and the "overheated period," when we want to avoid it.
   - C. *Shading calculations* are based on the maxim that throughout the year in underheated times the sun should strike the building, and in overheated times the structure should be in shade. A chart of the sun's path, plus geometric and radiation calculations, can describe the effectiveness of shading devices.
   - D. *Housing forms* and building shapes should conform to favorable or adverse impacts of the thermal environment; accordingly certain shapes are preferable to others in given surroundings.
   - E. *Air movements* can be divided into the categories of winds and breezes, according to their desirability. Winds occurring at underheated periods should be intercepted, cooling breezes should be utilized in overheated periods. Indoor air movement should satisfy bioclimatic needs. Calculations based on rate of airflow through a building in combination with inside flow patterns may be used to determine the location, arrangement, and sizes of openings.
   - F. *Indoor temperature balance* can be achieved to a certain degree with careful use of materials. Both time-lag and insulation characteristics of materials can be utilized for improved indoor conditions. Heliothermic planning, based on heat-flow studies, gives quantitative measures for the relative importance of the building elements. The criteria for balance are: minimum heat-flow out of building in wintertime, minimum heat-gain in the structure during the overheated period.
4. Architectural Application of the findings of the first three steps must be developed and balanced according to the importance



of the different elements. Climate balance begins at the site, and should be taken into consideration at the housing layouts, with similar careful consideration given to the individual dwelling units.

SUMMARY

The contents of this book follow, in general, the four steps outlined. If the reader is first acquainted with the bioclimatic requirements of Chapter 2, he may the more easily follow the climatic evaluations in Chapter 3, and better understand the selective handling of climatological factors described in Chapter 4.

From there on the text does not follow each climatic constituent separately; rather, with the architectural result in mind, it emphasizes architectural elements and principles. No rigid recommendations are made, since there are many ways in architecture to approach the goal of human comfort. However, to emphasize the environmental factors which motivate regional variation, comparisons are developed in most of these chapters in four diverse geographic locations, representative of the major United States climate zones. This leads to the detailed consideration of the problems of orientation, shading, form of buildings, air movement, and heliothermic planning in Chapters 6 through 10.

At this point, the investigations could close. However, architects tend to be visually inclined and do not readily imagine life in the form of cumbersome graphs. They prefer to look at assembled conclusions, so Chapter 12 summarizes the effects of climate on buildings in the four main regions, with examples illustrating possible applications.

The adaptation of building to environment has been a continuous problem throughout the centuries. Vitruvius' recognition of its importance is echoed by Le Corbusier: "The symphony of climate . . . has not been understood. . . . The sun differs along the curvature of the meridian, its intensity varies on the crust of the earth according to its incidence. . . . In this play many conditions are created which await adequate solutions. It is at this point that an authentic regionalism has its rightful place."[18]