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ECOLOGICAL ENGINEERING OF THE CITY

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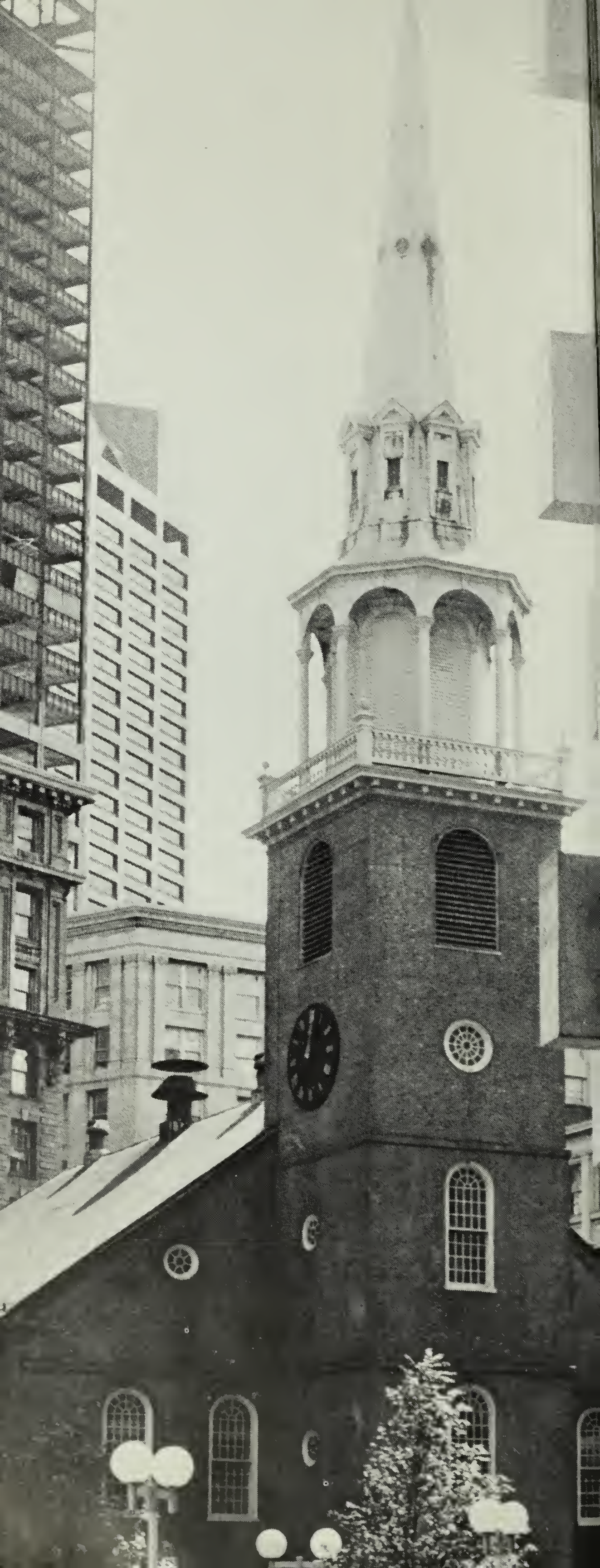
The Urban Ecosystem



The cities of the world are great engineering feats. From the earliest habitats of man constructed out of the raw materials of his environment man has used his ingenuity to work engineering wonders that improve the circumstances of his existence. Since most of the ancient cities we have come to know had already reached a high state of development, it is difficult to realize the long transition of engineering from early, simple hunting camps, hamlets, and villages to the spectacularly engineered urban centers that are Peking, Paris, Rome, or New York. Yet this transition did occur over time, and its earliest manifestations must have expressed themselves in much the same form as elementary human habitations existing in many parts of the world today. The important fact is that man, through his engineering technological skills, has steadily altered the environment and his habitat to suit whatever activity was currently thought to be important.

The most ancient cities of which we have records contained colossal engineering works. At Babylon were constructed two of the wonders of the ancient world; they would be wonders in any age. They were the hanging gardens and the walls of the city's main line of fortification.

The hanging gardens were built in terraces so large that residences with full-grown trees could be accommodated with the other garden plantings. The city walls were of double construction—an outer wall, 10 feet thick and 55 feet high, and an inner wall, 25 feet thick and 55 feet high. A 50-foot space separated the two walls.

Long after Babylon faded into history and became "interesting mounds" in that region between the Tigris and Euphrates, the bricks of the city were "mined" and reused to build many other cities of the area.

The Babylonians did not restrict their engineering skills to buildings and fortifications. They developed extensive canals and irrigation systems that transformed the desert into a garden and controlled the distribution of water for agriculture and transportation.

It was not mere happenstance that such a civilization occurred. The ingredients for a giant step were at hand, and in such a mix that it required control of only one factor—the river waters—to produce an environment tremendously favorable to man. Control of water in the fertile crescent, an engineering feat of no small magnitude, transformed the area from one hostile to man to one that produced food surpluses and, consequently, the knowledge and leisure time necessary to produce a great city.

The pyramids of Egypt, although they are not parts of cities and do not perform any function normally considered part of city life, nevertheless represent an engineering *tour de force* by people already settled into cities. The building of the pyramids recently has been hypothesized as the first public works project. It provided the potential for year round employment and commonness of purpose, thus laying the groundwork for the establishment of the first true nation. Although their direct utilitarian purpose now is obscured, the scope of the engineering involved is indicative of the intellectual and technological skill of the people. In Egypt too, man had mastered the techniques of irrigation and reaped the benefits of an engineered environment in which food was plentiful and citizens were freed to develop civilized arts and crafts.

Other engineering feats illustrate the technical prowess of early city builders; the Great Wall of China and the pyramid building of Central America are two examples. One of the high points in engineering was the iron-making technology of the Etruscans who settled parts of the Italian peninsula before the Romans. They developed arts and crafts to a high degree, including schools of higher learning, and they also mastered the arts of agricultural engineering and successfully applied swamp drainage and irrigation systems to create productive agriculture. If the artwork of the funerary remains is an indication, the Etruscans were a happy and contented people.

The size of their iron industry for that day is overwhelming. The Italian government has "mined" the large mounds of iron ore found in the vicinity of some of the ancient Etruscan ironworks and produced from these mounds which were a sizeable proportion of the steel used by Italy in World War II which were the slag heaps from the ancient Etruscan smelters.

Little is known of the effects of these developments on the health and well-being of those who labored to accomplish them, but it is probable that these technological advances were achieved at great cost to their health and well-being. However it is unlikely that the labor on such a great engineering project as the hanging gardens of Babylon affected the life expectancy of the laborers compared to the non-laborers of that day. The same water-borne diseases that plague those areas today did so when the canals and irrigation ditches of the Babylonian or Egyptian countryside were built, and must have taken a substantial toll then, as now. Only recently have schistosomiasis and malaria been understood well enough to be coped with, and even modern medicine leaves us with a difficult struggle.

So the building of the early cities exacted their price—not only because the work was difficult, but also because cities concentrated people and increased the threat of contagious disease. Nevertheless, the advantages outweighed the disadvantages, and the growth of cities progressed steadily for 20,000 years.

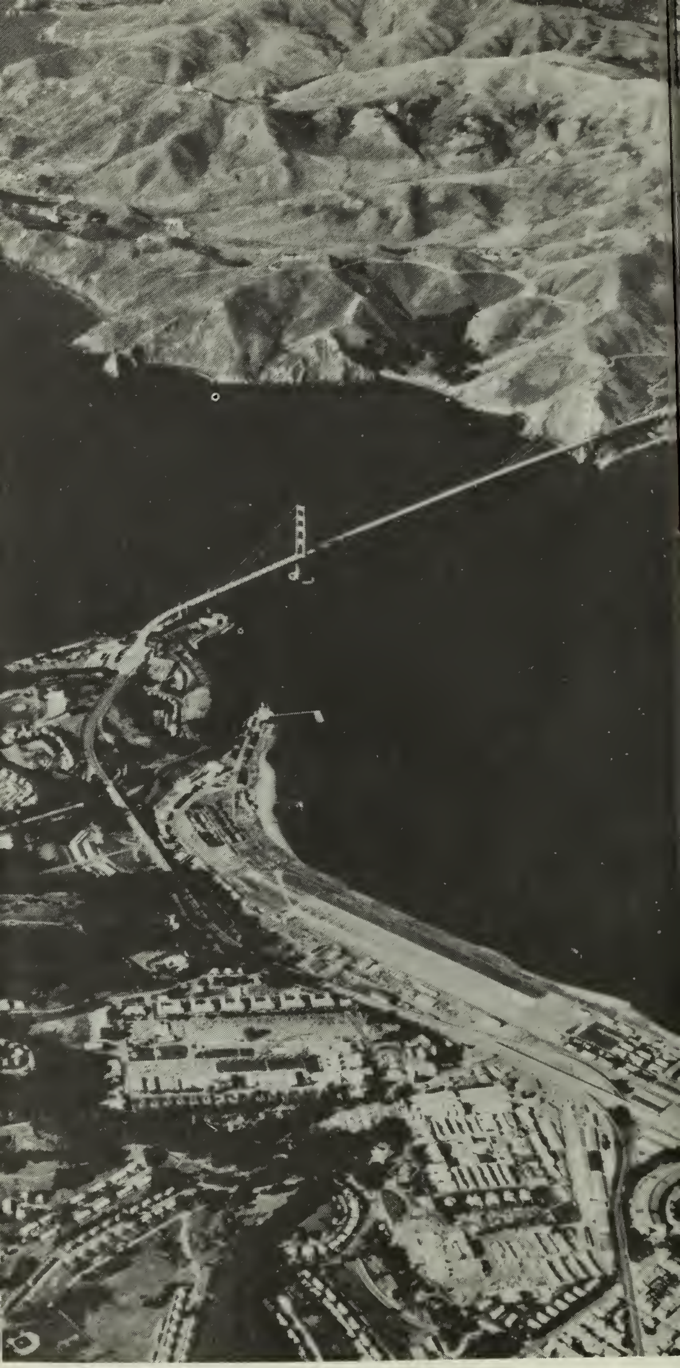
Started as experiments to exploit the advantages of selected environments, cities soon became the hubs of industry and wealth production where information could be exchanged easily and surplus wealth was available to convert information and ideas into the 3-dimensional reality of the engineered world. This reality was not man-centered; it was wealth- and power-centered.

The first cities proved conducive to the enhancement of man's technological abilities, and offered an additional bonus, livability. This quality of livability was a "side effect" of their having been built to accommodate man—the principal instrument of labor. Recent studies of ancient Greek cities demonstrate this point. The spatial relations of these cities were such that all the parts were readily accessible on foot by all inhabitants and walking was the principal means of locomotion. The living conditions might consist of squalor; the work might indeed be life shortening; but the spatial arrangement, similar to stables that accommodate draft animals, had the built-in relationships of a human ecological community. As machine labor supplanted human labor, cities would be built to accommodate the industrial machines of man in preference to man himself—proving that cities design themselves around the work "force." Still later, cities would be built to accommodate the automobile. But the early cities had only to accommodate man—the draft animal. The concept may have been crude and passive, but it was effective environmental engineering. At a higher level of both awareness and humanity we are turning to this concept again, but now it is called "passive design."

The living quarters of such ancient cities as Catalhuyuk, on the Anatolian Plain of Turkey, seem to have incorporated elements of defense as well as comfortable living, and it is not surprising to find comparable dwellings in the modern world. The houses were entered not by doors in the vertical walls but by holes through the roof, access to which was gained by ladders. That the culture was high even for the 13th century B.C., is evidenced by the complexity of stonework, which included decorative items. The masonry and construction also were quite advanced. There is no doubt that Catalhuyuk was a city in every sense of the word and its structure and function are understandable, even if all the individual tools are not.

The Aztec capital city, perhaps more than any other of its day, illustrates the city as marketplace. When Cortez first viewed the central marketplace of Tenochtitlan, he was amazed at its size, extent, and complexity. He was awed by the numbers of merchants doing business and by the orderliness of the process. Vendors with similar products were grouped in common lanes of the market, as were offerers of services, such as barbers. The proximity of so much commercial activity in such a compact, ordered structure points up the physical attributes of information exchange and its effects on the business life of the community. Perhaps at no place in Europe could such a market have been found at that time. While this Tenochtitlan accomplishment may not rank as an engineering feat comparable to the pyramids of Egypt or the wall of Babylon, it illustrates genius in terms of human engineering and human ecology. The New York Stock Exchange is no more advanced an idea.

The evolution of cities seems to have involved technological devices that took advantage of local raw materials and market centers that utilized the proximity of buyers and sellers to build a rudimentary information system of commerce. Many cities were planned and built to serve special functions, such as manufacturing and industrial centers, administrative seats of government, *entrepot* centers for the transportation of goods, etc. In most cases, as long as the technology was human-scaled, the cities well and conveniently served the people who lived in them. They probably incorporated living food sources in the form of animals and may



even have included agricultural plants within or nearby. As technology increased in scope, the cities shifted from cottage-based industry to cities "zoned" for industry; the cities developed within walking distance of the industry.

One can wonder how the towns and cities of the industrial revolution might have developed if electricity had been discovered before the steam engine. Did construction of the single huge, centralized steam power source cause the stratification of industrial functions, in effect supplanting cottage industry and causing the industrial "zoning?" Would electricity have kept industry human-sized and dispersed? Not only did spatial separation begin with the advent of heavy industry but social stratification was accentuated as well.

A modern city incorporates all the evolutionary stages of city development. So little is known (or applied) about the human ecology of the city that few improvements in cities have occurred in any way other than by happenstance. The proximity factors that seem so important as an ameliorating ambiance in city life did not develop as a convenience to city inhabitants, but to satisfy conditions of business, commerce, or industry. The fact that many of these areas of cities make good neighborhoods after-the-fact is an accident of history. We turn around and see how the system "self-designs" and then set these historic results up as future goals.

The advances in transportation engineering are the main force behind suburban explosion in the United States. First came train transportation from which arose the suburbs of New York. Since the places the train served were established communities, local transportation at first worked to maintain towns and villages. But when the automobile with its door-to-door service became the principal means of commuting, the phenomenon of suburban sprawl was off and running.

Actually, a number of engineering events occurred simultaneously. First, the atomic bomb was invented and used; at the end of World War II there was a drastic shortage of housing; the automobile manufacturers, plugging into increased capacity and demand created by the war, geared up to produce all the cars the nation could conceivably use; and, finally, the proliferation of cars was coincidentally coupled to the construction of the National Defense Highway system. The result changed the face of the nation. Every city of 100,000 was to be connected by interestate highways, and each city was also to have a beltway built to interstate standards. Such a system was to provide needed transportation corridors for the evacuation of cities in the event of nuclear war or its threat, and for years, as the interstate system was being built, the blue evacuation signs pointed the way out of all the cities of the nation. At the same time, the black and yellow fallout shelter signs appeared everywhere, and the nation as a whole was exhorted to build personal "civilian defense" shelters.

The nation failed to respond to the call to build shelters, but it *did* respond to the new highway system.

Technological developments in the housing industry produced mass housing and U.S. Levittowns sprang up like mushrooms on cheap land made accessible by the mycelium of the growing highway system. In many cities the first beltway was followed by the "outer" beltway, and flight from the inner cities proceeded at breakneck pace. Unforeseen in the original design of the highway system was its rapid saturation by automobiles. The Long Island Expressway was soon dubbed "the longest parking lot in the world," and the highway system designed to evacuate a bomb-threatened populace instead produced a colossal accident toll that someday may approach the fatality score it was originally designed to avert.

The Pennsylvania Turnpike was our first superhighway, and it is hard to believe that it had no separation of opposing roadways and an unlimited speed. Accidents involving 50 or 60 cars became commonplace and hours-long traffic delays because of accidents were ordinary driving experiences. It is estimated that on the Los Angeles freeway system, for every minute traffic is delayed by an accident, ten minutes are required to restore traffic to normal flow.

Workers commuting in and out of Washington, D.C., also are in a paradoxical situation and regularly exceed the posted speed limits. If they drive slower because of rain, snow, or other hazardous conditions and the traffic moves at or below the speed limit, great buildups occur throughout the system. The occasional driver who is ticketed for speeding during the rush hour presents the paradox of the hapless culprit at the side of the road, with the police-car lights flashing and officer in full view, while traffic whizzes past them at speeds over the limit.

The drive-in movie, the drive-in bank, the supermarket with its acres of parking, the drive-in restaurant—each in its own way contributes to the engineering of the automobile society, with its houses on quarter-acre lots spread over thousands of acres of farmland, sidewalkless streets, and school buses. This situation has produced a stratified economy, not only socially but economically.

Because suburban living requires greater instead of less income, inequities in the supply of services occur, straining the budgets not only of the suburbs but of the central cities as well. Central cities, with their utilities essentially paid for until entropy exacts its maintenance toll, were abandoned to low-income families. High-income families live in a suburb, work in a city, require services from both city and suburb, but pay taxes only to one.

The increased interest in the science of ecology and the curtailment of our most common energy sources are combining to produce some interesting alternatives for a society in which energy was thought to be limitless and in which personal transportation was considered a necessity.

The use of the personal automobile made it possible to build diffuse human settlements. Single family, detached dwellings predominate, and shopping centers cluster around huge parking lots with services convenient to drivers. The land used for such schemes was farmland near the city made accessible by the new road systems and economically attractive because of the price differential between farm acreage and suburban building lots. Land suitable for development became so valuable from the tax standpoint that it was impossible to keep it in agriculture. The large amount of money involved overcame most resistance, and high taxes did the rest.

Providing services to such communities was expensive; utilities and sewerage disposals had to be extended great distances to accommodate thinly spread, individual residences. The objective of suburban living was "space" to contrast with city living, and "green spaces" to contrast with the grey drabness of central cities. Suburbs were places to park cars and where green lawns, trees, shrubs, gardens, and other amenities associated with "country" living were found.

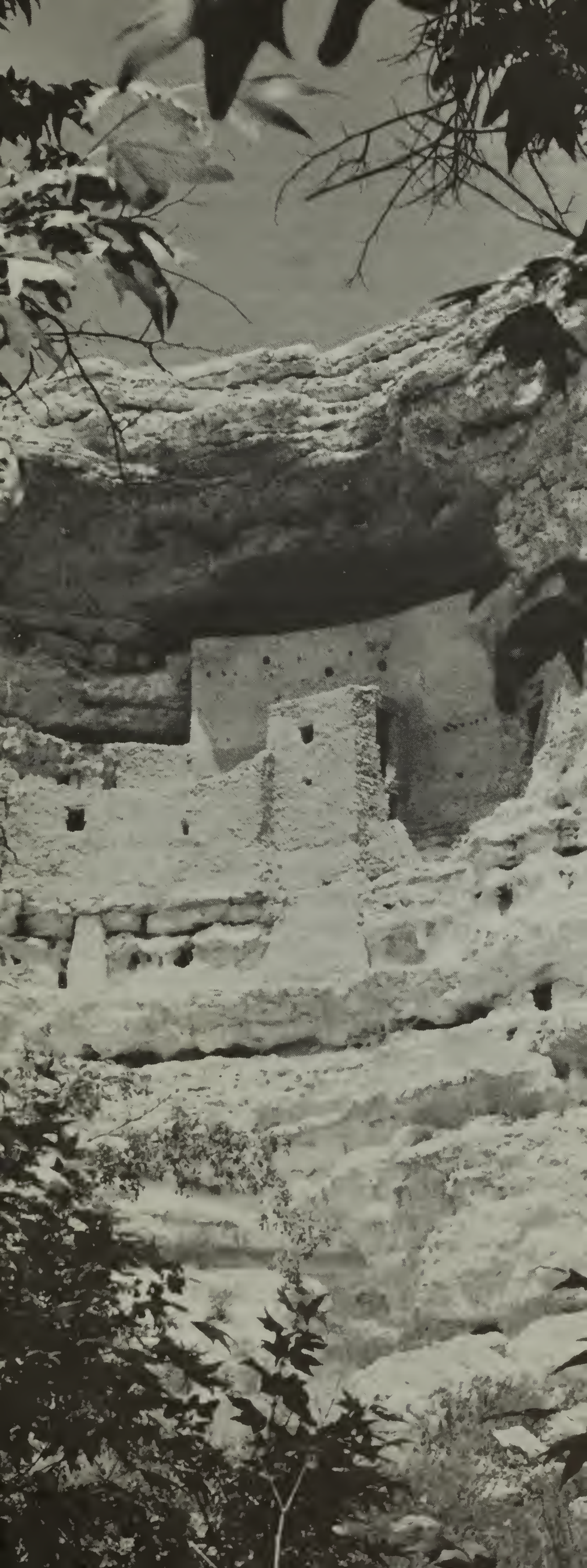
The zoning laws usually were such that houses of restricted size and value were built on certain tracts, shoving the suburbs further toward economic stratification. Restricted price classes also restricted the size of houses, and attracted for the most part couples with young children.

Since the youngsters were bused to schools and the parents drove to work, to the grocery, and to other required goods and services, nondrivers who lived in such communities were trapped. The cost of public transportation for people scattered in such diffuse settings was prohibitive, and using public transportation was a sign of lower status in a community where the number of cars indicated family status. Two cars became a necessity for most families, and three or four became commonplace as the children reached driving age.

The engineering considerations of suburban living had to take account of the paradox of providing goods and services on a mass scale to a diffusely settled population. The costs incurred were high, but the income status of persons resorting to suburban living provided the necessary economic basis for such development. The central cities languished as more and more farmland was dedicated to suburban living. In many areas the flight to the suburbs was so rapid that capacity of existing utilities, particularly sewerage, soon was exceeded; the provision of services became the factor limiting the growth of suburbs.

From an engineering standpoint, the design and construction of the suburbs was shaped primarily by the automobile; without it the modern suburb makes little sense. Human values were sacrificed for the convenience of personalized transportation. Ecologically, the suburbs became single factor ecosystems, with enormous dependence on *the* single factor—the automobile.

Transportation corridors into and out of most cities are clogged with heavy traffic twice a day and are essentially empty at other hours. In the Washington, D.C., area, an entire bridge crossing the Potomac River is restricted to 4-passenger carpools and buses. Roads designed for high speed, low volume traffic are clogged with low speed, high volume traffic. Mere reduction in the number of lanes results in buildups, and stopping at toll booths backs up rush hour traffic into 12-mile long, inching lanes at the Mid-town Tunnel



in New York. An accident during the rush hour brings traffic to a complete halt.

At the opposite end of the density scale from the suburbs stands the highrise apartment.

The skyscraper is an American invention. In Chicago, a group of skyscrapers that together represent the historical development of this architectural engineering form has been designated a National Historic Site. The skyscraper and its smaller cousin, the highrise, provide great economy in the use of land for construction. All these forms are related to apartment dwellings, an ancient architectural form. It appeared in the medieval city, in the cliff dwellings of southwest United States, and all through the Indian architecture of Central and South America. The single large building that housed many people or functions is an old invention, but the *very* large building, the megastructure, is a recently developed, related concept.

The skyscraper and highrise arose as a single-purpose concept, in contrast to the clustering in medieval cities. They were either office buildings or dwellings, never both. In modern cities the construction of skyscrapers and highrises has resulted in severe stratification of population. The Wall Street area of Manhattan illustrates this in the extreme. The area is densely used during working hours but virtually deserted at night. Since there are distinctly different tax benefits relating to business and to residence occupancies, and since the benefits are mostly tilted toward business (in the form of deductions from income tax for the cost of doing business), the stratification tends in the direction of highly segregated business construction.

The concept of "the megastructure" is comparatively new, welding the ancient multifunctional city concept with the modern skyscraper technology and combining all the functions necessary for city operation into one structure. The megastructure would include manufacturing and industry, business and commerce, educational and recreational facilities. Contained within it would be all the services and goods necessary to operate a city, including human residences. The principal means of transportation would be walking, aided by escalators and elevators.

The concept of the megastructure presents in compact form the engineering problems of building for the functional needs of the city—its industry and commerce—and at the same time engineering the environment of its inhabitants.

The term "bio-engineering—is presently used to describe the medical application of engineering to severe human problems of prosthesis. The artificial limbs and eyeglasses of yesterday have been extended to highly sophisticated engineering devices and systems that aid not only in the mechanical, but the biochemical, metabolic, and physiologic problem areas as well. Heart pacemakers are commonplace; powered with long-lived batteries, they regulate the heartbeat of individuals whose biological pacemaker can no longer handle the job. Kidney machines to dialyze body fluids can replace normal kidney function. The devices and machinery to perform human biological functions continue to grow.

But the concept of engineering to provide an essential biological function need not be limited to the functions of an individual. The same concept can be put to use in the larger human environment. To address the structure of a city as though it were a human ecological structure would allow for analysis and solution of many pressing city problems.

The city is a biological community and behaves like one. It is natural therefore to assume that if the biological properties of the city were recognized, proper engineering considerations could be given to solving the biological problems they raise. In short, the city would be ecologically engineered if in fact it were recognized and reorganized as a biological community.

The construction of large-domed stadia to produce uniform climatic conditions for mass-mediated spectator sports has realized the old science fiction concept of the contained city, independent of the climate of the planet's surface. While restricted energy budgets may be spelling the end of wasteful single-use structures of this kind, the need for energy efficiency may very well provide the impetus to turn this level of engineering into more humanly efficient paths.

The Astrodome and the Superdome are not cities by any stretch of the imagination, but they do accommodate 80 to 100 thousand people and fill a great variety of their needs for periods up to

4 or 5 hours per day. The extension of the climate-controlled city concept is not far beyond that of the Superdome, and it relates directly to the megastructure idea.

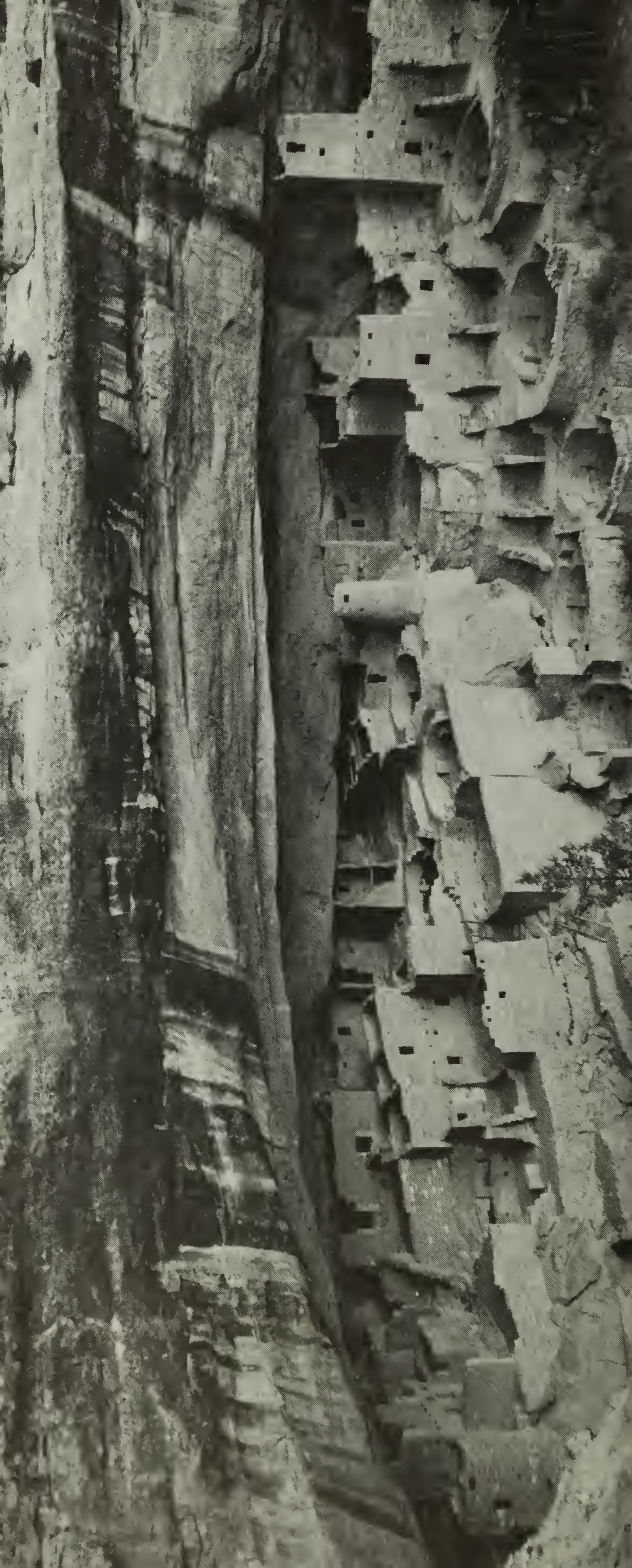
One way to consider the megastructure is as a "packing" phenomenon packing a city of 250,000 into a cube 5,280 feet on each side. Start by taking all the elements of the city; normal consideration would tell us we are dealing with a myriad of independent structures. But are we really? The buildings of a city are all connected to the same power grid; they are all connected to the same water and sewer system; and they easily may be connected to a common fuel system. The city has a common two-way communication system in the telephone and one-way communication is tuned to a common radio/TV system.

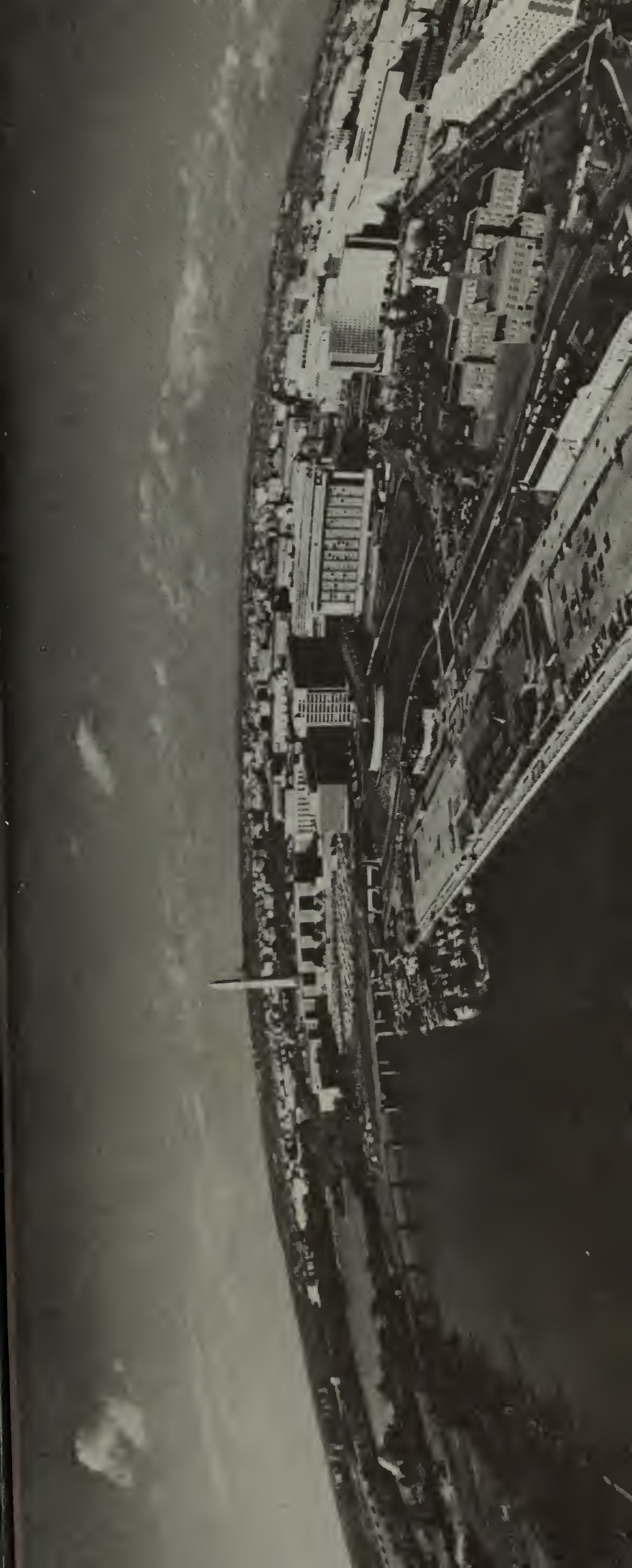
The city is like a giant patch of mushrooms—seemingly independent entities but connected by a pervasive mycelium of communication and service networks. In addition, the city is completely interconnected by transportation corridors—streets, railways, canals, bus routes, auto routes, truck routes, and subways and metros. Each house and building of the city is plugged into the communications, water system, waste disposal, transportation, and power grids. In many respects the modern city is a model of a megastructure, in which only two of a very plausible three dimensions predominate.

The transition between the present-day city and the megastructure is primarily one of spacing—proximity, or packaging concepts that would alter ecological distances and spatial relations and enhance ecological stability.

All engineering of the city has implicitly expressed human ecological relationships, but only because these relationships are inescapable. The fact is that human ecological relationships were poorly understood until recently and most of the great cities of the world are quite old. Building cities primarily to provide opportunities for business, commerce, and industry has been the guiding principle since the very beginning of cities, so it is not surprising that people have been accommodated in the city largely as an afterthought. That is to say, the requirements of man—the biological/ecological animal—were provided only after all other reasons for building the city were satisfied. The suburbs too were designed to satisfy only a portion of the spectrum of human requirements and even these only for the middle span of years. Suburbs suit the home buyers, not necessarily their children or their parents.

The ecological requirements for properly engineering the human community should be just as susceptible to understanding and execution as are the biological requirements which we now satisfy by means of bioengineering for the individual person. The community of human



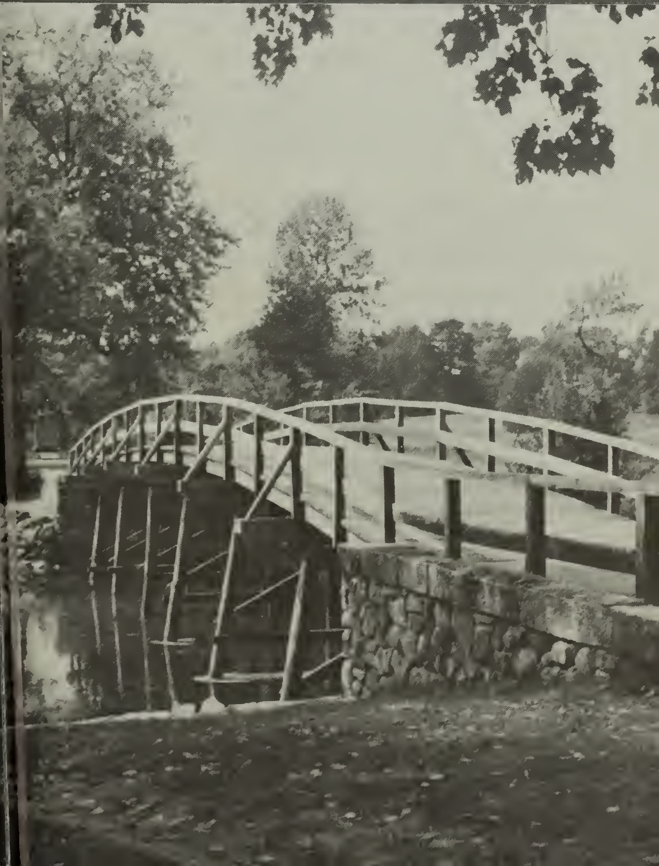


beings can be enhanced by engineering technology in the same way that an individual's functioning can be improved by an electronic limb, a pacemaker, or a kidney machine. What is required is an understanding of the ecological principles and relations governing human communities and the will to engineer these characteristics into the human system. We know what some of them are because we have accidentally built them into our cities.

Recent engineering efforts find us groping toward some of the concepts which are embodied in Habitat, EXPO 67's hit, and engineered amusement centers such as Disneyland and Disney World. We have learned that large numbers of people can be moved, fed, and amused in relatively small spaces, what we still lack is a systematic approach to the human ecology in general and particularly the ecology of human habitation. The city has yet to be recognized as a human ecosystem, and so we still lack the advantages such an insight could bring.

The business, commerce, and industry interests that are the principal factors controlling the structure of the urban ecosystem tend to be a vast collection of single-factored entities, the major effort being to maximize economic gain. Taken as a collection of activities, these functions interrelate and complement each other and provide the real basis for the formation of the city. But when viewed as individual processes it can be seen that, although many of the processes are ecologically related, they continue to operate independently because they are not perceived as an ecological system. Hence, great waste and duplication occur.

Activities which should be functionally and spatially related remain separated and segregated, with human ecology being ignored to accommodate technological and economic conditions. Combined office and living buildings are rare, for instance, because the tax factors for each are so remarkably different. Industrial parks segregate workers from their living areas; large office structures rely upon minimum design standards to provide essentially single function spaces; various sized offices and office suites are formed by rearranging the movable interior wall panels. The replication of only a few simple utilities makes it possible to provide suitable space for a wide variety of office work—because an



office requires only a relatively few utilities to accommodate all office functions. Total living would require a great many more utilities and other features, and that would complicate the design of the building. It is by no means impossible to engineer living-working functions into the same building, but the present economic climate simply makes it unprofitable to do so.

But suppose that the same building included living quarters and services as well as working space. Heating and/or air conditioning for the work spaces could be switched to "off" when the spaces were not in use, but the encased nature of the space (interspersed with living and services spaces) would tend to keep the work space temperatures at or near workable levels—obviating the necessity of heating and cooling over long periods of non-use such as weekends and holidays, or else spending extra energy to bring such spaces back to working condition temperatures after shut-downs.

The Concept of "Human Ecosystem"

At this point it becomes useful to examine the concept of ecosystem in a general way, to relate the concept of ecosystem to human beings, and then to see how engineering could enhance the functioning of the human ecosystem.

The term ecosystem has been used to describe so wide a variety of ecological conditions that its use could be confusing to the nonecologist. We begin with ecology as the science of living organisms in relationship to their environment. An ecosystem is living organisms and their physical/chemical environment, and the interrelation among all the biological and physiochemical factors that affect them.

An ecosystem must be viewed as a functioning *whole,* because it operates as a *system* and not as a group of independent processes. Ecosystems follow thermodynamic laws in exactly the same way physical systems do and consequently they posses the same elements of predictability and control. Ecosystems differ from physical systems in that they contain living organisms which can and do adapt to changing conditions, sometimes in surprising ways. In short, because of their ability to react to environmental circumstances, the living organisms within the system can arrange themselves to optimize or maximize their potential within the system. The ecosystem can be said to be "self-designing" as it comes to equilibrium with the thermodynamic conditions of its being.

The complexity of ecosystems arises not out of some reservoir of innate complexity, but from the number of outcomes that are possible through the interaction of a few simple but greatly replicated parts. Various organisms have given spectra of responses to environment; the conditions which favor some do not favor others and vice versa.

As conditions change, the composition of living organisms within the ecosystem may change and these changes will occur as long as conditions that can support life exist. The group of organisms that best fits the conditions at any time will predominate; as conditions change a new set of organisms better suited to the conditions may take its place.

The essential point is that through the chemistry and physics of life the group of organisms best able to survive and thrive in an environment is the group that will tend to occupy it. This is a positive,

forceful event that is driven by primary energy sources; locally it seems to defy the second law of thermodynamics, because it proceeds from disorder and goes to order; it moves for the most part from less complex to more complex arrangements, and it requires a steady input of energy to maintain it. Human ecosystems meet these requirements to the same extent that other biological ecosystems do and they may *increase* in complexity and order or *decrease* in complexity and order, depending upon the energy inputs and other ecological factors. The question before us is to understand the nature of the energy inputs, to understand the ecological factors and their relationships, and to engineer our human ecosystems taking this information into account.

The term ecosystem causes some confusion because the word has been applied to a great variety of situations of differing complexity—ranging from the relations of single organisms and their limited environment to the totality of all living things and their complex environment: the earth and its energy source, the sun.

One strong emphasis in the study of ecosystems is that *living organisms must be considered in the context of their physiochemical environment* and that the continuum of conditions from the nonliving to the living must be understood in order to understand living systems. The other strong concept is *the probabilistic nature of ecosystems.* In this regard their conceptual origins are presumed to be similar to physical systems and more particularly to the probabilistic notion that any particular ecosystem is one form of many that could just as probably have arisen at that some place. This would indicate that even closely related ecosystems are not carbon copies of each other, but that they are related through the *probability* of their origin and development in the same way that the views through a kaleidoscope are related—each one different but all composed of the same bits of glass or metal, the gravity pull that acts on them as the tube is turned, and the light which reflects from their surfaces. The resulting designs have great similarity, are generated by the same processes, and contain the same ingredients, yet they are all different—but not so different that the relationships among them cannot readily be seen and alike in that environmental factors affect them the same way.

Prior to coining the word ecosystem, ecologists had an array of terms to describe community and environmental conditions. These terms are still in common usage and are used integrally and synonymously with ecosystem.

The term ecosystem can apply equally well to the simplest and the most complex. It is useful therefore to consider orders of ecosystems based upon their complexity. Such a proposition results in a list of ecosystems arranged in order of complexity:

Order	**General Description**	**Social Human Version**
1st order Ecosystem	An organism in the context of environment	An individual in the context of family
2nd Order Ecosystem	Community	Neighborhood—clan
3rd Order Ecosystem	Association	The city—tribe
4th Order Ecosystem	Biome	The nation or group of nations
5th Order Ecosystem	Biosphere	Geopolitical world (noösphere or "sphere of the mind")
6th Order Ecosystem	Solar System	Man on the Moon, Probes to Mars, and the planets of our solar system
7th Order Ecosystem	Galaxy	Attempts to communicate with life in other solar systems
8th Order Ecosystem	Universe	Attempts to comprehend the size, complexity, and nature of the universe

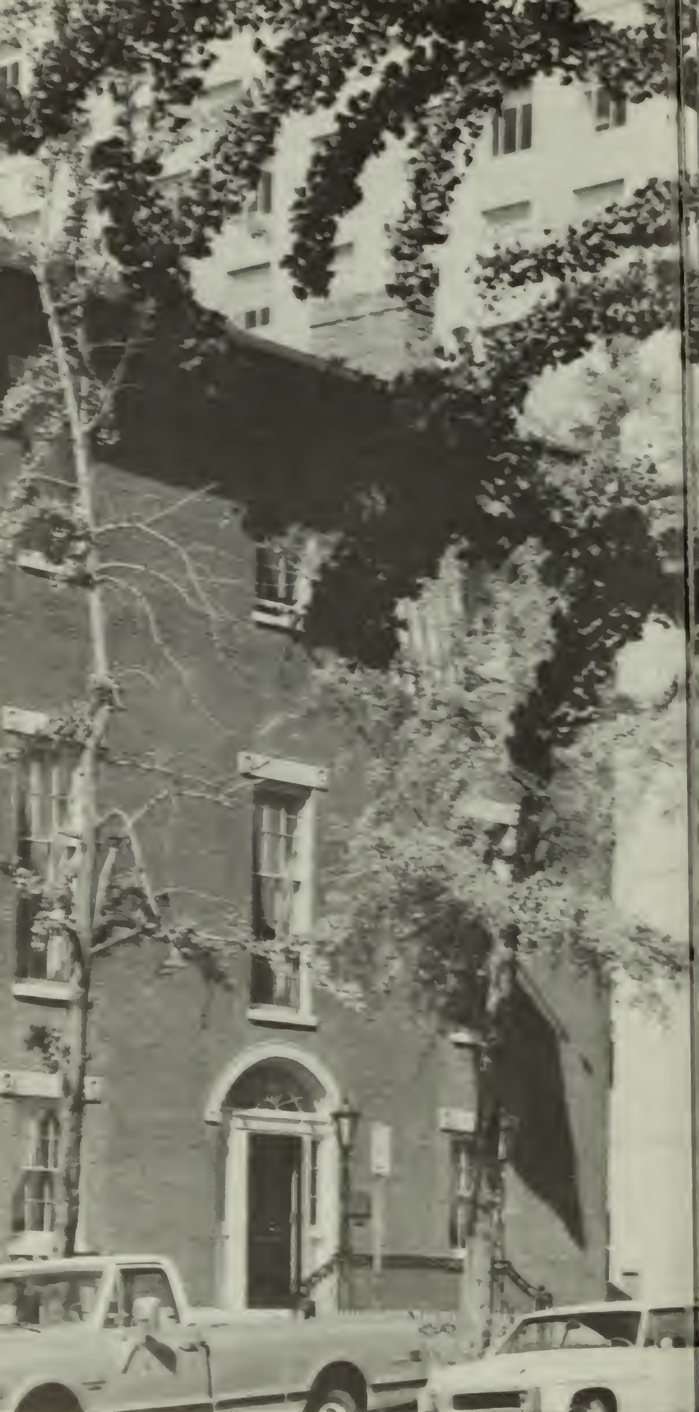
While it is interesting to consider all eight orders of ecosystems, of immediate concern for us are the first three. Perhaps the most important use of this conceptual design is to see each order of ecosystem providing the building blocks for the next higher order of ecosystem and to become aware of the manner in which more complex ecosystems are formed out of the interrelatedness of the simpler subsidiary units.

It is inconceivable that a member of the species *Homo sapiens* could arise as a "human being" without direct interaction with other human beings, the Tarzan myth notwithstanding. The most usual context for this process of aculturization is the family. While it is not an absolute requirement that each and every individual be reared and educated as a human being by his/her own biological family, it is necessary through human intervention that the functions that would have been performed by the family be performed by some person or persons. This is an axiomatic part of our thinking, yet the ramifications of it seem not to be understood or given appropriate consideration at the times when ecological engineering is taking place. If such considerations were given their due, the initial engineering task would be to arrange the first order ecosystem correlates not just to favor the individual, but more specifically to do so in the context of the family.

The problem of engineering the environmental requirements of the family will depend in part on the structure of the family and the perceived relationship between its members. The most current notion of the American family is the so-called nuclear family—parents and their children. The nuclear family is in its present configuration probably because of the high mobility of the population as a whole. Not only is there mobility with respect to means of physical transportation, but with respect to social status as well. A great many young people leave home, go to a distant city to attend school, and literally never return.

Much of the rural-to-urban migration occurs because job opportunities are more prevalent in cities than in rural areas—and this is occurring at a time when farms are becoming more highly mechanized. Many work functions formerly performed on farms are being performed on the same products but in city processing plants.

For whatever reason, therefore, American families tend to be nuclear and tend to lose their younger members to college or distant employment. If one of our objectives is to produce ecologically sound family unity, some of the ecological relationships of families and their



environmental requirements must be examined. Ecological communities are characterized by having members of all ages. If the nuclear family were to develop (or revert) to the "extended family" (including once again the entire or larger span of family generation), the all-age attribute would be restored. But economic opportunity may not permit three generations of the same family to live together or close by. The engineering problem is to provide the environmental circumstance to permit community members of the three age groups to live proximally and to provide opportunities to members of these age groups to function as members of an extended family. From the standpoint of engineering and city planning, this calls for a closer look at the way individual dwellings are designed with respect to their interior spatial relations, and the way dwellings of all sizes are arranged with respect to all other community elements.

The highrise apartment building and suburbia share one characteristic in common—they tend to segregate a single age and income group. Suburbs tend to be designed for the family with children and highrises for the family without.

Some notable exceptions such as Cedar-Riverside in Minneapolis have tried to accommodate both divergent income groups and divergent age groups. But this is a self-conscious effort against the mainstream where for the most part, domiciles are segregated by age, income, and lifestyle factors. This tends to increase the required mobility of the population since the dwelling area in question may be efficient only during part of the life cycle.

The situation in some European countries, where individualized transportation has not produced the urban sprawl of the United States but where urban immigrations have produced severe housing shortages, has forced the three generations often to occupy the same crowded quarters—an ecologically destabilizing situation because of lack of space. In Prague, where this condition obtains, city planners are designing domiciles specifically to accommodate the three generations; for while there are distinct disadvantages from the crowding aspect, great economic advantages obtain when space is adequate. These advantages include the possibility for interdependency in task performance among all members of the three generation family and the creation of a learning/living environment in which youngsters grow up interacting with all age groups and consequently absorbing a better idea of the operation of the human community as a totality.

They participate in all the ceremonies, rites of passage, funerals, and other events of the community as a whole, and therefore experience firsthand their own humanness in an operational human environment.

From a strict engineering point of view, a great deal has yet to be done to lower the cost of housing and the cost of operating and maintaining individual domiciles. Passive design features for the conservation of energy have scarcely begun, and the design of domiciles to utilize environmental energy sources has made only the smallest beginning.

At present, solar energy is used primarily for light. Windows extend our sense of space and permit the entry of light. In an energy-conscious economy, windows account for energy loss from the heating budget of the house. Solar collectors, either to capture heat energy or to convert the energy of photons to the energy of electricity, have yet to be utilized to any significant degree. The benefits from having domiciles more energy independent include not only long-run energy savings, but the fostering of environmental awareness that the domicile is embedded in its immediate environment.

Second order ecosystems are biological communities. In the human context they are the various different neighborhoods of cities. The neighborhood is the basic community element of the city. To function as a community the neighborhood must first be recognized as such by its inhabitants. Any system that does not function is dead, and cities today are full of dead neighborhoods. We have so preoccupied ourselves with the architecture of buildings that we have rarely looked to the larger problem of the architecture of the *community*.

Foremost among the biological attributes of communities is the characteristic of diversity. Diversity is one of nature's great devices for achieving stability; in biological communities diversity is achieved either through differences in life forms or differences in species. In the human community, since we are only one species and since our life form variation is only in the growth, maturation, and senescence cycle, it would appear that there could not be much diversity. However, since the city and most human communities are based upon technology, we must look to a different kind of diversity to understand this principle in the human community.

Organisms classified according to their *genetics* are called genotypes. A group of closely related genotypes are called *biotypes.* Those classified by their *ecological* requirements are called *ecotypes.* These classifications allow for the analysis of ecological problems involving the genetics of any species whatever and the ability of two different species to occupy similar ecological niches. These suffice for nonhuman biological communities.

What is required for the human community is an additional classification based upon the *technological* function of the human organisms. The term *technotype* is proposed to describe this function of the human community. Genetically an individual may be male or female, caucasoid, mongoloid, capoid, negroid, or australoid (the races of man). These attributes aid in the classification of *biotypes.* Ecotypically, the individuals may be forest people, prairie people, or mountain people—attributes that relate to people as *ecotypes.* But when the modern human urban community is examined it is obvious that this is not enough; we want to know if the individual is the butcher, the baker, or the candlestick maker; the doctor, lawyer, chief; or merchant it is in this realm of technological function that we look for the *technotypes.*

Man as a species has a rather low diversity when it comes to biotypes or ecotypes. But in the realm of technology, man has proliferated himself into thousands of different technotypes, and it is the attribute of diversity related to technotypes to which we must look to see this important principle of human communities.

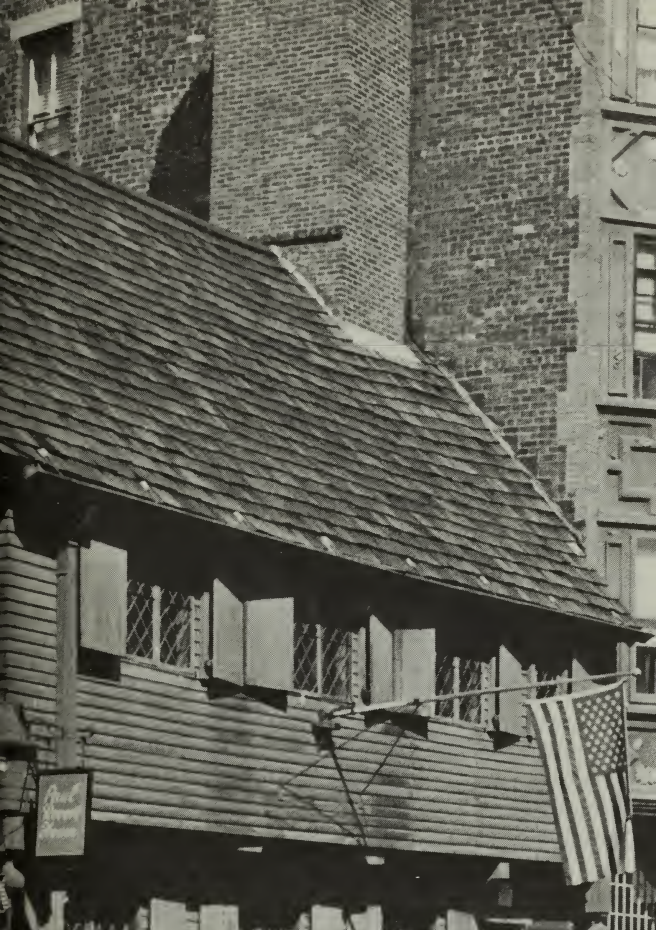
As an aside we should note that other species of animals that do have technology such as ants and termites have evolutionarily solved this diversity problem by physiological specialization into the workers, soldiers, queens, etc. Man obviously is not physiologically specialized, but rather is educationally specialized—his specialization is a function of his technology, not of his genetics.

If we look at the diversity of technotypes in the human community, the ecological principle of diversity and stability becomes immediately apparent. Communities in which employment opportunities are restricted, either in numbers or types, are much more prone to sudden drastic change than communities in which a great variety of jobs is available for large numbers of people. The one-industry town that folds when the one industry closes down is a classic case in point. Rural communities that serve only the farmers and farm families of a restricted area fluctuate economically along with the fluctuations of the farm commodities market. Even large industrial areas, such as automotive manufacturing centers, suffer greater than average hardships when the auto industry is in a slump. On the other hand, cities with a wide variety of light, medium, and heavy industry may scarcely feel an economic recession, since the majority of workers will not be concentrated in any one business or industry. Thus, the list of occupations for a given area can be examined and segregated by business enterprise, and it will provide a ready index to the community's economic stability.

From the ecological viewpoint, what can be said about how to engineer communities so as to encompass great technotypic variability and thus achieve economic stability? For one thing, the technological feasibility of altering zoning concepts to safely agglomerate diverse business, commerce, and industrial functions with housing functions could be examined. Control of pollution may well be the key to feasibility of spatially locating diverse business and industrial functions close to each other and to the residential elements of the city.

Not only should it be possible for persons to live close to their place of employment but to many other needed facilities and services as well (doctors, food markets, clothing shops, banks, theaters, etc.).

The growth and development of cities could in all probability be gauged by the flux of technotypes in and out of the city. A study of the disappearance of small towns in Minnesota used the closing of the banks as the final indication of the demise of the town. Undoubtedly other businesses were more sensitive indicators than the banks and left earlier, but the closing of the bank leaves no doubt about the demise of economic viability for business and commercial enterprises. It is to be presumed conversely that when a new bank opens in an area, settlement has reached the status of a viable community. In Grand Canyon National Park, urbanization has reached the point where a shopping center with a



bank did open, clearly the visible manifestation of the arrival at the canyon's rim of an economically stable human community, albeit one whose human components are rapidly interchangeable.

Using the concept of the technotype, the analysis of the predictable stability or instability of the city is possible and has the same ecological consequences as analyzing the ecological diversity of biotypes and ecotypes. It is at this level of the third order ecosystem that the ecological engineering of the city will have the greatest impact. Third order ecosystems build up from first and second order ecosystems, but it is the relationship of these units to each other and their replication in the matrix of urban technological business and industrial development that will determine the ecological soundness of the city and ultimately its fitness as a human habitation.

For ecosystems higher than the third order, the overwhelming considerations are communications and transportation factors. Prior to high speed transportation and communication, fourth order human ecosystems tended to be restricted to components that could be managed easily under the constraints of long delays in communication time. Now, however, there appears to be no limit to the administrative potential, since worldwide communication is instantaneous and worldwide physical travel is possible in hours.

The facility with which communication and transportation encourage business and social ties between widely dispersed peoples has given rise to the concept of the "symbolic community." This concept is useful, but it is not the overriding concern for the survival or development of the human community, because the place where the important biological/ecological functions must occur determines the viability of the human community.

What is experienced as a result of high-speed communication is technological accommodation. Most long-distance communication takes place as part of a business, commercial, industrial, or governmental information network that serves primarily technological administration purposes and not human ecological needs. It is easy to confuse technological complexes with human ecological ones, but that is only because the humans in such complexes serve technological, not ecological functions. There is, to be sure, an "ecology of technology" but it takes us away from the biological aspects of human ecology.

The engineering aspects of industrial development on a world scale do have an impact on the biosphere as a whole. The biosphere as a fifth order ecosystem has been virtually insensitive to the activities of man for most of the time man has spent on earth. The biosphere changed only in response to worldwide changes in weather and to tectonic and other geological forces—but for most of man's time on earth, the biosphere was beyond the scale of anything humans could do.

Recently that has changed. With technology increasing at breakneck speed, changes now transcend locality and produce ramifications far beyond those conceived by the humans who trigger the actions. The digging of the Suez Canal connected two water bodies of biospheric dimension that had been isolated for millenia. Livestock grazing in Europe has considerably altered the pattern of vegetation. Pollution has affected all parts of the globe. The testing of atomic weapons in the atmosphere caused widespread dispersion of potentially dangerous radionuclide. As a matter of fact, the distribution of the radionuclide Strontium 90 from point sources (weapons explosions) even to the marrow of unborn babies probably did more than anything else to demonstrate the unity of the atmosphere and the living world's mutual dependence on clean air.

The space age with its miracles of space travel will one day settle down to the comparatively mundane and routine task of gathering information about the earth and relaying information over the entire global surface. Space technology already has revolutionized navigation, has brought events of worldwide interest to the TV screens of hundreds of millions simultaneously, and has made highspeed, reliable communication a possibility between any two spots on earth—no matter how remote from each other. Insofar as mutual understanding of information exchange tends to lessen tensions among nations, our ventures into space technology should stabilize ecological conditions in our fifth order ecosystem; but insofar as the rockets are delivery systems for weapons and the earth-observing satellites are "spies in the sky," they will tend to destabilize it. If past technological development is an indication, the stability factors will prevail simply because they *are* stability factors.

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.