The Hidden Dimension

EDWARD T. HALL

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AUTHOR'S PREFACE

Generally speaking, two types of books interest the serious reader: those that are content oriented—designed to convey a particular body of knowledge—and those that deal with structure—the way in which events are organized. It is doubtful if an author has any control over which of these two types of books he or she writes, though it is desirable to be aware of the difference. The same applies to the reader whose satisfaction depends largely on unstated expectations. Today, when all of us are overwhelmed with data from many sources, it is easy to understand why people feel that they are losing touch, even in their own field. In spite of television, or possibly because of it, people feel a loss of relatedness to the world at large. Information overload increases the need for organizing frames of reference to integrate the mass of rapidly changing information. *The Hidden Dimension* attempts to provide such an organizing frame for space as a system of communication, and for the spatial aspects of architecture and city planning.

Books of this type, since they are independent of disciplinary lines, are not limited to a particular audience or field. This lack of disciplinary orientation will disappoint readers searching for pat answers and those who wish to find everything classified in terms of content and profession. However, since space relates to everything, it is inevitable that this book would cross disciplinary lines.

In writing about my research on people's use of space—the space that they maintain among themselves and their fellows, and that they build around themselves in their cities, their homes, and their offices—my purpose is to bring to

awareness what has been taken for granted. By this means, I hope to increase self-knowledge and decrease alienation. In sum, to help introduce people to themselves.

Regarding the organization of the book, I must mention that as an anthropologist I have made a habit of going back to the beginning and searching out the biological substructures from which human behavior springs. This approach underscores the fact that humankind is first, last, and always a biological organism. The gulf that separates humans from the rest of the animal kingdom is not nearly as great as most people think. Indeed, the more we learn about animals and the intricate adaptation mechanisms evolution has produced, the more relevant these studies become for humans in their search for the solution to many complex human problems.

All of my books deal with the *structure of experience as it is molded by culture*, those deep, common, unstated experiences which members of a given culture share, which they communicate without knowing, and which form the backdrop against which all other events are judged. Knowledge of the cultural dimension as a vast complex of communications on many levels would be virtually unnecessary if it were not for two things: our increasing involvements with people in all parts of the world, and the mixing of subcultures within our own country as people from rural areas and foreign countries pour into our cities.

It is increasingly apparent that clashes between cultural systems are not restricted to international relations. Such clashes are assuming significant proportions within our own country and are exacerbated by the overcrowding in cities. Contrary to popular belief, the many diverse groups that make up our country have proved to be surprisingly persistent in maintaining their separate identities. Superficially, these groups may all look alike and sound somewhat alike, but beneath the surface are manifold unstated, unformulated differences in their structuring of time, space, materials, and relationships. It is these very differences that often result in the distortion of meaning, regardless of good intentions, when peoples of different cultures interact.

As a consequence of writing this book, I have been invited to lecture to hundreds of architectural audiences all over the

[illegible] is a consequence of the joint efforts of a team. There are always particular members of the team whose roles are more clearly defined and without whose help the manuscript would never have reached the publisher. It is the contribution of these people that I wish to acknowledge.

The nature of communication is such that in its early, ill-defined stages any utterance lies partly revealed on paper while the rest, and often the most essential part, is hidden in the author's mind. He does not know this, however, because in reading his own manuscript he automatically inserts the missing parts. The first need for an author, therefore, is for someone to stick with him and to put up with his exasperated and often hostile response when it is pointed out that he has failed to distinguish clearly between what he knows and what he has written. For me, writing is something which one does not do casually. When I am writing, everything else stops. This means that other people have to carry a heavy burden. My first acknowledgment is, as always, to my wife, Mildred Reed Hall, who is also my partner in my work and who assisted me in my research in so many ways that it is often difficult to separate her contributions from mine.

Support for my research has been generously provided by grants from the National Institute of Mental Health. The Wenner-Gren Foundation for Anthropological Research and the Human Ecology Fund have provided essential aid and support for travel to the field and for equipment and funds to help defray the heavy expense incurred in the preparation of the manuscript.

I wish to make special mention of that unique institution, the Washington School of Psychiatry, its Board of Directors and its faculty and staff. As a Research Fellow of the School and a member of its faculty for many years, I profited enormously from my interaction with this creative group. The Washington School provided sponsorship for my research and a stimulating, accepting atmosphere in which to work.

The following editors aided me in the production of this manuscript: Roma McNickle of Boulder, Colorado, Richard Winslow and Andrea Balchan of Doubleday, and my wife, Mildred Reed Hall. Without their help I could not have produced this volume. I received valuable and loyal assistance

the language of space is just as different as the spoken language. Most important of all, space is one of *the* basic, underlying organizational systems for all living things—particularly for people. Why these statements are true is the subject of this book.

No book reaches a point suitable for publication without the active cooperation and participation of a great many people, all essential. There are always particular members of the team whose roles are more clearly defined and without whose help the manuscript would never have reached the publisher. It is the contribution of these people that I wish to acknowledge.

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I also wish to acknowledge and thank the following for permission to quote: Harcourt, Brace & World for Antoine de St. Exupéry's *Flight to Arras* and *Night Flight;* Harper & Row for Mark Twain's *Captain Stormfield's Visit to Heaven;* Houghton Mifflin for James J. Gibson's *The Perception of the Visual World;* Alfred A. Knopf, Inc., for Franz Kafka's *The Trial* and for Yasunari Kawabata's *Snow Country,* UNESCO Series of Contemporary Works (Japanese Series), translated by Edward G. Seidensticker; *Language* for Edward Sapir's "The Status of Linguistics as a Science"; Massachusetts Institute of Technology for Benjamin Lee Whorf's *Science and Linguistics;* The Technology Press and John Wiley & Sons for Benjamin Lee Whorf's *Language, Thought, and Reality;* the University of Toronto Press for Edmund Carpenter's *Eskimo;* and *The Yale Review,* Yale University Press for Edward S. Deevey's "The Hare and the Haruspex: A Cautionary Tale."

Some of the material in Chapter X appeared previously in my article titled "Silent Assumptions in Social Communication," published in the proceedings of the Association for Research in Nervous and Mental Disease. Permission to use this material is gratefully acknowledged.

THE HIDDEN DIMENSION

I

CULTURE AS COMMUNICATION

The central theme of this book is social and personal space and man's perception of it. Proxemics is the term I have coined for the interrelated observations and theories of man's use of space as a specialized elaboration of culture.

The concepts developed here did not originate with me. Over fifty-three years ago, Franz Boas laid the foundation of the view which I hold that communication constitutes the core of culture and indeed of life itself. In the twenty years that followed, Boas and two other anthropologists, Edward Sapir and Leonard Bloomfield, speakers of the Indo-European languages, were confronted with the radically different languages of the American Indians and the Eskimos. The conflict between these two different language systems produced a revolution concerning the nature of language itself. Before this time, European scholars had taken Indo-European languages as the models for *all* languages. Boas and his followers discovered in effect that each language family is a law unto itself, a closed system, whose patterns the linguist must reveal and describe. It was necessary for the linguistic scientist to consciously avoid the trap of projecting the hidden rules of his own language on to the language being studied.

In the 1930s Benjamin Lee Whorf, a full-time chemist and engineer but an amateur in the field of linguistics, began studying with Sapir. Whorf's papers based on his work with the Hopi and Shawnee Indians had revolutionary implications for the relation of language to both thought and perception. Language, he said, is more than just a medium for expressing thought. It is, in fact, *a major element in the formation of thought.* Furthermore, to use a figure from our own day, man's very perception of the world about him is programmed by

the language he speaks, just as a computer is programmed. Like the computer, man's mind will register and structure external reality only in accordance with the program. Since two languages often program the same class of events quite differently, no belief or philosophical system should be considered apart from language.

Only in recent years, and to just a handful of people, have the implications of Whorf's thinking become apparent. Difficult to grasp, they became somewhat frightening when given careful thought. They strike at the root of the doctrine of "free will," because they indicate that all men are captives of the language they speak as long as they take their language for granted.

The thesis of this book and of *The Silent Language*, which preceded it, is that the principles laid down by Whorf and his fellow linguists in relation to language apply to the rest of human behavior as well—in fact, to all culture. It has long been believed that experience is what all men share, that it is always possible somehow to bypass language and culture and to refer back to experience in order to reach another human being. This implicit (and often explicit) belief concerning man's relation to experience was based on the assumptions that, when two human beings are subject to the same "experience," virtually the same data are being fed to the two central nervous systems and that the two brains record similarly.

Proxemic research casts serious doubt on the validity of this assumption, particularly when the cultures are different. Chapters X and XI describe how people from different cultures not only speak different languages but, what is possibly more important, *inhabit different sensory worlds*. Selective screening of sensory data admits some things while filtering out others, so that *experience as it is perceived* through one set of culturally patterned sensory screens is quite different from experience perceived through another. The architectural and urban environments that people create are expressions of this filtering-screening process. In fact, from these man-altered environments, it is possible to learn how different peoples use their senses. Experience, therefore, cannot be counted on as a stable point of reference, because it occurs in a setting that has been molded by man.

The role of the senses in this context is described in Chapters IV through VII. This discussion was included to give the reader some of the basic data on the apparatus man uses in building his perceptual world. Describing the senses in this way is analogous to descriptions of the vocal apparatus as a basis for understanding speech processes.

An examination of how the senses are used by different peoples, as they interact with their living and non-living environment, provides concrete data on some of the differences between, for example, Arabs and Americans. Here at the very source of the interaction it is possible to detect significant variations in what is attended and what is screened out.

My research of the past five years demonstrates that Americans and Arabs live in different sensory worlds much of the time and do not use the same senses even to establish most of the distances maintained during conversations. As we shall see later, Arabs make more use of olfaction and touch than Americans. They interpret their sensory data differently and combine them in different ways. Apparently, even the Arab's experience of the body in its relation to the ego is different from our own. American women who have married Arabs in this country and who have known only the learned American side of their personality have often observed that their husbands assume different personalities when they return to their homelands where they are again immersed in Arab communication and are captives of Arab perceptions. They become in every sense of the word quite different people.

In spite of the fact that cultural systems pattern behavior in radically different ways, they are deeply rooted in biology and physiology. Man is an organism with a wonderful and extraordinary past. He is distinguished from the other animals by virtue of the fact that he has elaborated what I have termed *extensions* of his organism. By developing his extensions, man has been able to improve or specialize various functions. The computer is an extension of part of the brain, the telephone extends the voice, the wheel extends the legs and feet. Language extends experience in time and space while writing extends language. Man has elaborated his extensions to such a degree that we are apt to forget that his humanness is rooted in his animal nature. The anthropologist Weston La Barre

has pointed out that man has shifted evolution from his body to his extensions and in so doing has tremendously accelerated the evolutionary process.

Thus any attempt to observe, record, and analyze proxemic systems, which are parts of modern cultures, must take into account the behavioral systems on which they are based as expressed by earlier life forms. Chapters II and III of this book should help to provide both a foundation and a perspective to be used in considering the more complex human elaborations of space behavior in animals. Much of the thinking and interpretation of data that went into this book has been influenced by the tremendous strides made in recent years by ethologists, the scientists who study animal behavior and the relation of organisms to their environment.

In light of what is known of ethology, it may be profitable in the long run if man is viewed as an organism that has elaborated and specialized his extensions to such a degree that they have taken over, and are rapidly replacing, nature. In other words, man has created a new dimension, the cultural dimension, of which proxemics is only a part. The relationship between man and the cultural dimension is one in which both *man and his environment participate in molding each other*. Man is now in the position of actually creating the total world in which he lives, what the ethologists refer to as his biotope. In creating this world he is actually determining *what kind of an organism* he will be. This is a frightening thought in view of how very little is known about man. It also means that, in a very deep sense, our cities are creating different types of people in their slums, mental hospitals, prisons, and suburbs. These subtle interactions make the problems of urban renewal and the integration of minorities into the dominant culture more difficult than is often anticipated. Similarly, our lack of full understanding of the relation of peoples *and* their biotope is compounding the process of technical development of the so-called underdeveloped nations of the world.

What happens when people of different cultures meet and become involved? In *The Silent Language* I suggested that communication occurs simultaneously on different levels of consciousness, ranging from full awareness to out-of-awareness. Recently it has become necessary to expand this view. When people communicate they do much more than just toss the conversational ball back and forth. My own studies as well as those of others reveal a series of delicately controlled, culturally conditioned servomechanisms that keeps life on an even keel, much like the automatic pilot on the airplane. All of us are sensitive to subtle changes in the demeanor of the other person as he responds to what we are saying or doing. In most situations people will at first unconsciously and later consciously avoid escalation of what I have termed the adumbrative or foreshadowing part of a communication from the barely perceptible signs of annoyance to open hostility. In the animal world, if the adumbrative process is short-circuited or bypassed, vicious fighting is apt to occur. In humans in the international-intercultural sphere of life many difficulties can be traced to failure to read adumbrations correctly. In such instances, by the time people discover what is going on, they are so deeply involved that they can't back out.

The following chapters include many instances of the thwarting of communication primarily because neither of the parties was aware that each inhabits a different perceptual world. Each was also interpreting the other's spoken words in a context that included both behavior and setting, with a result that positive reinforcement of friendly overtures was often random or even absent.

Indeed, it is now believed by ethologists such as Konrad Lorenz that aggression is a necessary ingredient of life; without it, life as we know it would probably not be possible. Normally, aggression leads to proper spacing of animals, lest they become so numerous as to destroy their environment and themselves along with it. When crowding becomes too great after population buildups, interactions intensify, leading to greater and greater stress. As psychological and emotional stress builds up and tempers wear thin, subtle but powerful changes occur in the chemistry of the body. Births drop while deaths progressively increase until a state known as population collapse occurs. Such cycles of buildup and collapse are now generally recognized as normal for the warm-blooded vertebrates and possibly for all life. Contrary to popular belief, the food supply is only indirectly involved in these cycles,

as demonstrated by John Christian and V. C. Wynne-Edwards.

As man developed culture he domesticated himself and in the process created a whole new series of worlds, each different from the other. Each world has its own set of sensory inputs, so that what crowds people of one culture does not necessarily crowd another. Similarly, an act that releases aggression and would therefore be stressful to one people may be neutral to the next. Nevertheless, it is fairly obvious that the American Negroes and people of Spanish culture who are flocking to our cities are being very seriously stressed. Not only are they in a setting that does not fit them, but they have passed the limits of their own tolerance to stress. The United States is faced with the fact that two of its creative and sensitive peoples are in the process of being destroyed and like Samson could bring down the structure that houses us all. Thus it must be impressed upon architects, city planners, and builders that if this country is to avoid catastrophe, we must begin seeing man as an interlocutor with his environment, an environment which these same planners, architects, and builders are now creating with little reference to man's proxemic needs.

To those of us who produce the income and pay the taxes which support government, I say that whatever the cost of rebuilding our cities, this cost will have to be met if America is to survive. Most important, the rebuilding of our cities must be based upon research which leads to an understanding of man's needs and a knowledge of the many sensory worlds of the different groups of people who inhabit American cities.

The chapters that follow are intended to convey a basic message about the nature of man and his relationship to his environment. The message is this:

There is a great need to revise and broaden our view of the human situation, a need to be both more comprehensive and more realistic, not only about others, but about ourselves as well. It is essential that we learn to read the silent communications as easily as the printed and spoken ones. Only by doing so can we also reach other people, both inside and outside our national boundaries, as we are increasingly required to do.

II

DISTANCE REGULATION IN ANIMALS

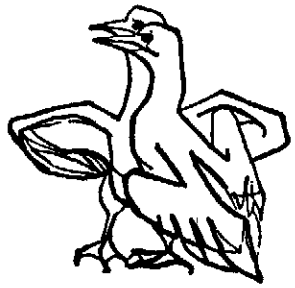
Comparative studies of animals help to show how man's space requirements are influenced by his environment. In animals we can observe the direction, the rate, and the extent of changes in behavior that follow changes in space available to them as we can never hope to do in men. For one thing, by using animals it is possible to accelerate time, since animal generations are relatively short. A scientist can, in forty years, observe four hundred forty generations of mice, while he has in the same span of time seen only two generations of his own kind. And, of course, he can be more detached about the fate of animals.

In addition, animals don't rationalize their behavior and thus obscure issues. In their natural state, they respond in an amazingly consistent manner so that it is possible to observe repeated and virtually identical performances. By restricting our observations to the way animals handle space, it is possible to learn an amazing amount that is translatable to human terms.

Territoriality, a basic concept in the study of animal behavior, is usually defined as behavior by which an organism characteristically lays claim to an area and defends it against members of its own species. It is a recent concept, first described by the English ornithologist H. E. Howard in his *Territory in Bird Life*, written in 1920. Howard stated the concept in some detail, though naturalists as far back as the seventeenth century had taken note of various events which Howard recognized as manifestations of territoriality.

Territoriality studies are already revising many of our basic ideas of animal life and human life as well. The expression "free as a bird" is an encapsulated form of man's conception

of his relation to nature. He sees animals as free to roam the world, while he himself is imprisoned by society. Studies of territoriality show that the reverse is closer to the truth and that animals are often imprisoned in their own territories. It is doubtful if Freud, had he known what is known today about the relation of animals to space, could have attributed man's advances to trapped energy redirected by culturally imposed inhibitions.

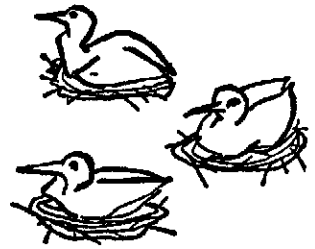


Many important functions are expressed in territoriality, and new ones are constantly being discovered. H. Hediger, Zurich's famous animal psychologist, described the most important aspects of territoriality and explained succinctly the mechanisms by which it operates. Territoriality, he says, insures the propagation of the species by regulating density. It provides a frame in which things are done—places to learn, places to play, safe places to hide. Thus it co-ordinates the activities of the group and holds the group together. It keeps animals within communicating distance of each other, so that the presence of food or an enemy can be signaled. An animal with a territory of its own can develop an inventory of reflex responses to terrain features. When danger strikes, the animal on its home ground can take advantage of automatic responses rather than having to take time to think about where to hide.

The psychologist C. R. Carpenter, who pioneered in the observation of monkeys in a native setting, listed thirty-two functions of territoriality, including important ones

relating to the protection and evolution of the species. The list that follows is not complete, nor is it representative of all species, but it indicates the crucial nature of territoriality as a behavioral system, *a system that evolved in very much the same way as anatomical systems evolved.* In fact, differences in territoriality have become so widely recognized that they are used as a basis for distinguishing between species, much as anatomical features are used.

Territoriality offers protection from predators, and also exposes to predation the unfit who are too weak to establish and defend a territory. Thus, it reinforces dominance in selective breeding because the less dominant animals are less likely to establish territories. On the other hand territoriality facilitates breeding by providing a home base that is safe. It aids in protecting the nests and the young in them. In some species it localizes waste disposal and inhibits or prevents parasites. Yet one of the most important functions of territoriality is proper spacing, which protects against overexploitation of that part of the environment on which a species depends for its living.

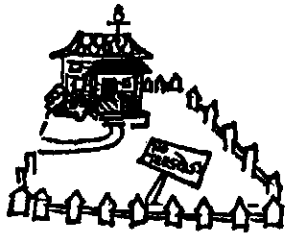


In addition to preservation of the species and the environment, personal and social functions are associated with territoriality. C. R. Carpenter tested the relative roles of sexual vigor and dominance in a territorial context and found that even a desexed pigeon will in its own territory regularly win a test encounter with a normal male, even though desexing usually results in loss of position in a social hierarchy. Thus, while dominant animals determine the general direction in which the species develops, the fact that the subordinate can win (and so breed) on his home grounds helps to preserve plasticity in the species by increasing variety and thus preventing the dominant animals from freezing the direction which evolution takes.

Territoriality is also associated with status. A series of experiments by the British ornithologist A. D. Bain on the great tit altered and even reversed dominance relationships

by shifting the position of feeding stations in relation to birds living in adjacent areas. As the feeding station was placed closer and closer to a bird's home range, the bird would accrue advantages it lacked when away from its own home ground.

Man, too, has territoriality and he has invented many ways of defending what he considers his own land, turf, or spread. The removal of boundary markers and trespass upon the property of another man are punishable acts in much of the Western world. A man's home has been his castle in English common law for centuries, and it is protected by prohibitions on unlawful search and seizure even by officials of his government. The distinction is carefully made between private property, which is the territory of an individual, and public property, which is the territory of the group.



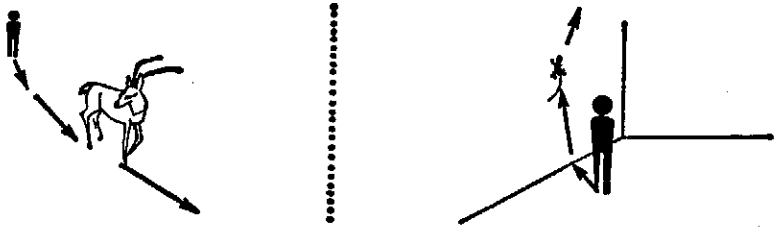
This cursory review of the functions of territoriality should suffice to establish the fact that it is a basic behavioral system characteristic of living organisms including man.

SPACING MECHANISMS IN ANIMALS

In addition to territory that is identified with a particular plot of ground, each animal is surrounded by a series of bubbles or irregularly shaped balloons that serve to maintain proper spacing between individuals. Hediger has identified and described a number of such distances which appear to be used in one form or another by most animals. Two of these —flight distance and critical distance—are used when individuals of *different species meet;* whereas personal distance and social distance can be observed during interactions between members of the same species.

Flight Distance

Any observant person has noticed that a wild animal will allow a man or other potential enemy to approach only up to a given distance before it flees. "Flight distance" is Hediger's term for this interspecies spacing mechanism. As a general rule, there is a positive correlation between the size of an animal and its flight distance—the larger the animal, the greater the distance it must keep between itself and the enemy. An antelope will flee when the intruder is as much as five hundred yards away. The wall lizard's flight distance, on the other hand, is about six feet.

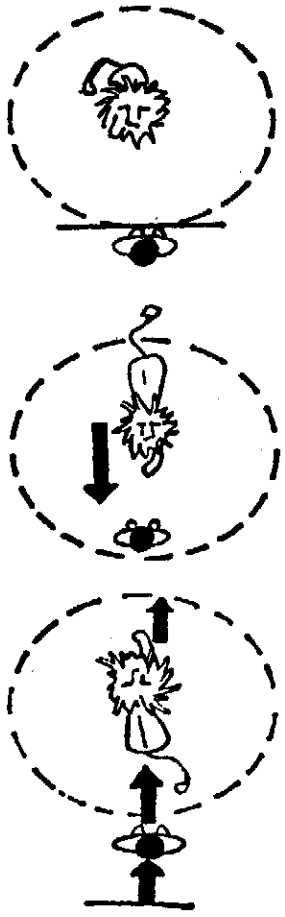


There are, of course, other ways of coping with a predator, such as camouflage, protective armor or spines, or offensive odor. But flight is the basic mechanism of survival for mobile creatures. In domesticating other animals, man has had to eliminate or radically reduce the flight reaction. In zoos, it is essential to modify the flight reaction enough so that the captive animal can move about, sleep, and eat without being panicked by man.

Although man is a self-domesticated animal, the domestication process is only partial. We see this in certain types of schizophrenics who apparently experience something very similar to the flight reaction. When approached too closely, these schizophrenics panic in much the same way as an animal recently locked up in a zoo. In describing their feelings, such patients refer to anything that happens within their "flight distance" as taking place literally *inside themselves.* That is, the boundaries of the self extend beyond the body. These experiences recorded by therapists working with schizophren-

ics indicate that the realization of the self as we know it is intimately associated with the process of making boundaries explicit. This same relationship between boundaries and self can also be observed in cross-cultural contexts, as we shall see in Chapter XI.

Critical Distance



Critical distances or zones apparently are present wherever and whenever there is a flight reaction. "Critical distance" encompasses the narrow zone separating flight distance from attack distance. A lion in a zoo will flee from an approaching man until it meets an insurmountable barrier. If the man comtinues the approach, he soon penetrates the lion's critical distance, at which point the cornered lion reverses direction and begins slowly to stalk the man.

In the classical animal act in the circus, the lion's stalking is so deliberate that he will surmount an intervening obstacle such as a stool in order to get at the man. To get the lion to remain on the stool, the lion tamer quickly steps out of the critical zone. At this point, the lion stops pursuing. The trainer's elaborate "protective" devices—the chair, the whip, or the gun—are so much window dressing. Hediger says the critical distance for the animals he has knowledge of is so precise that it can be measured in centimeters.

Contact and Non-Contact Species

In regard to the use of space, it is possible to observe a basic and sometimes inexplicable dichotomy in the animal world. Some species huddle together and require physical contact with each other. Others completely avoid touching. No apparent logic governs the category into which a species falls. Contact creatures include the walrus, the hippopotamus, the pig, the brown bat, the parakeet, and the hedgehog among many other species. The horse, the dog, the cat, the rat, the muskrat, the hawk, and the blackheaded gull are non-contact species. Curiously enough, closely related animals may belong to different categories. The great Emperor penguin is a contact species. It conserves heat through contact with its fellows by huddling together in large groups and thus increases its adaptability to cold. Its range extends over many parts of Antarctica. The smaller Adelie penguin is a non-contact species. Thus it is somewhat less adaptable to cold than the Emperor, and its range is apparently more limited.

What other functions may be served by contact behavior are unknown. One could hazard a guess that, since contact animals are more "involved" with each other, their social organization and possibly their manner of exploiting the environment might be different from those of non-contact animals. Non-contact species, one would think, would be more vulnerable to the stresses exerted by crowding. It is clear that all warm-blooded animals begin life in the contact phase. This phase is only temporary with the many non-contact species, for the young abandon it as soon as they leave their parents and are on their own. From this point in the life cycle of both types, regular spacing between individuals can be observed.

Personal Distance

Personal distance is the term applied by Hediger to the normal spacing that non-contact animals maintain between themselves and their fellows. This distance acts as an invisible bubble that surrounds the organism. Outside the bubble two

organisms are not as intimately involved with each other as when the bubbles overlap. Social organization is a factor in personal distance. Dominant animals tend to have larger personal distances than those which occupy lower positions in the social hierarchy, while subordinate animals have been observed to yield room to dominant ones. Glen McBride, an Australian professor of animal husbandry, has made detailed observations of the spacing of domestic fowl as a function of dominance. His theory of "social organization and behavior" has as a main element the handling of space. This correlation of personal distance and status in one form or another seems to occur throughout the vertebrate kingdom. It has been reported for birds and many mammals, including the colony of ground-living Old World monkeys at the Japanese Monkey Center near Nagoya.

Aggression is an essential component in the make-up of vertebrates. A strong, aggressive animal can eliminate weaker rivals. There seems to be a relation between aggression and display so that the more aggressive animals display more vigorously. In this way, too, display and aggression serve as handmaidens in the process of natural selection. To insure survival of the species, however, aggression must be regulated. This can be done in two ways: by development of hierarchies and by spacing. Ethologists seem to agree that spacing is the more primitive method, not only because it is the simplest but because it is less flexible.

Social Distance

Social animals need to stay in touch with each other. Loss of contact with the group can be fatal for a variety of reasons including exposure to predators. Social distance is not simply the distance at which an animal will lose contact with his group—that is, the distance at which it can no longer see, hear, or smell the group—it is rather a psychological distance, one at which the animal apparently begins to feel anxious when he exceeds its limits. We can think of it as a hidden band that *contains* the group.

Social distance varies from species to species. It is quite short—apparently only a few yards—among flamingos, and

quite long among some other birds. The late E. Thomas Gilliard, an American ornithologist, tells how clans of male bowerbirds maintain contact "over many thousands of feet by means of mighty whistles and harsh, rasping notes."

Social distance is not always rigidly fixed but is determined in part by the situation. When the young of apes and humans are mobile but not yet under control of the mother's voice, social distance may be the length of her reach. This is readily observed among the baboons in a zoo. When the baby approaches a certain point, the mother reaches out to seize the end of its tail and pull it back to her. When added control is needed because of danger, social distance shrinks. To document this in man, one has only to watch a family with a number of small children holding hands as they cross a busy street.

Social distance in man has been extended by telephone, TV, and the walkie-talkie, making it possible to integrate the activities of groups over great distances. Increased social distance is now remaking social and political institutions in ways that have only recently begun to be studied.

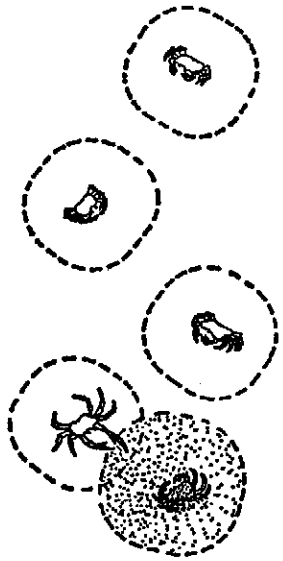
POPULATION CONTROL

In the cold waters of the North Sea lives a form of crab, *Hyas araneus*. The distinguishing feature of the species is that, at certain times in the life cycle, the individual becomes vulnerable to others of the same species, and some are sacrificed to keep the population down. Periodically, when the crab sheds its shell, its only protection is the space that separates it from crabs in the hard-shell stage. Once a hard-shelled crab gets close enough to scent his soft-shelled fellow—that is, once the olfactory boundary is passed—smell leads the hard-shelled predator to his next meal.

Hyas araneus provides us with an example of both a "critical space" and a "critical situation." These terms were originally used by Wilhelm Schäfer, Director of the Frankfurt Natural History Museum. Schäfer, in an attempt to understand basic life processes, was one of the first to examine the ways in which organisms handle space. His 1956 study was unique

in directing attention to crises of survival. Animal societies, he stated, build up until a critical density is reached, thus creating a crisis that must be met if the society is to survive. Schäfer's important contribution was to classify crises of survival and find a pattern in the various ways which simple forms of life have worked out to deal with the crowding that brings on such crises. Schäfer analyzed the process that relates population control to the solution of other important life problems.

As we have already seen, all animals have a minimum space requirement, without which survival is impossible. This is the "critical space" of the organism. When the population has built up so greatly that the critical space is no longer available, a "critical situation" develops. The simplest way of handling the situation is to remove some individuals. This can be accomplished in a variety of ways, one of which is illustrated by *Hyas araneus.*



Crabs are solitary animals. At the time in the life cycle when they must locate other crabs in order to reproduce, they find each other by smell. Thus the survival of the species depends on not having individuals roam so far apart that they cannot smell each other. But the critical space crabs need is also well defined. When their numbers increase to the point where critical space is not available, enough of those individuals who are in the soft-shell stage are eaten to bring the population back to a level at which individuals have enough room.

THE STICKLEBACK SEQUENCE

Several notches above the crab on the evolutionary scale is the stickleback, a small fish that is common in shallow fresh

waters in Europe. The stickleback was made famous when the Dutch ethologist Niko Tinbergen identified the complex sequence the fish has developed to reproduce itself. Tinbergen later showed that a short-circuiting of the sequence results in a population decrease.

In the spring, each male stickleback carves out a circular territory, defends it several times against all comers, and builds a nest. His inconspicuous gray coloring then changes, so that his chin and belly are bright red, his back blue-white, and his eyes blue. The change in coloration serves to attract females and repel males.

When a female, her belly swollen with eggs, comes within range of the stickleback's nest, the male zigzags toward her, alternately displaying his face and colorful profile. The two-step approach ceremony must be repeated several times before the female will follow the male and enter the nest. Shifting from the visual mode of communication to the more basic one of touch, the male with his nose rhythmically prods the female at the base of her spine until she lays her eggs. The male then enters the nest, fertilizes the eggs, and drives the female away. He repeats this sequence until four or five females have deposited eggs in his nest.

At this point the mating impulse subsides, and a new set of responses is observed. The male becomes his old inconspicuous gray. His role now is to defend the nest and keep the eggs supplied with oxygen by fanning water through the nest with his pectoral fins. When the eggs hatch, the male protects the young fish until they are big enough to fend for themselves. He will even catch those that wander too far, carrying them in his mouth carefully back to the nest.

The stickleback's behavior sequence—including fighting, mating, and caring for the young—is so predictable that Tinbergen was able to conduct a series of experiments which provides valuable insights into the message systems or signals that release responses to the different drives. The male's zigzag approach to the female is a response to an urge to attack, which has to run its course before the sexual urge takes over. The swollen shape of the egg-heavy female releases the courting response in the male. After she has laid her eggs, red no longer attracts her. She will not lay eggs until she

has been prodded by the male. Thus, vision and touch trigger the several elements of the sequence.

The predictable nature of the sequence enabled Tinbergen to observe in experimental situations what happens when the sequence is interrupted by the presence of too many males and consequent crowding of individual territories. The red of too many males disrupts courting. Some steps in the sequence are omitted so that eggs are not laid in a nest or fertilized. Under very crowded conditions, males will battle each other until some are killed.

MALTHUS RECONSIDERED

The crab and the stickleback provide useful information about the relation of space to reproduction and population control. The crab's sense of smell is the key to distance required by the individual and determines the maximum number of crabs that can inhabit a given area of the sea. In the stickleback, sight and touch set off an ordered sequence that must run its course if the fish is to reproduce. Crowding disrupts this sequence and thus interferes with reproduction. In both animals acuity of the receptors—smell, sight, touch, or a combination—determines the distance at which individuals can live and continue to perform the reproduction cycle. Without proper maintenance of this distance, they lose the battle to one of their own kind, rather than to starvation, disease, or a predator.

There is a growing need for reconsideration of the Malthusian doctrine which relates population to the food supply. For centuries, Scandinavians have watched the march of the lemmings to the sea. Similar suicidal activities have been observed among rabbits at the time of large-scale population buildups followed by die-off. Natives of certain Pacific islands have seen rats doing the same sort of thing. This weird behavior on the part of certain animals has led to every imaginable explanation, yet it wasn't until recently that some insight was gained as to the factors that lay behind the lemmings' mad dash.

About the time of World War II, a few scientists began

to suspect that there was more to population control than predators and food supply and that the behavior of lemmings and rabbits might bear on these other factors. At the time of large-scale die-offs, there appeared to be plenty of food available, and carcasses showed no signs of starvation.

Among the scientists studying this phenomenon was John Christian, an ethologist with training in medical pathology. In 1950 he advanced the thesis that increase and decrease in mammalian populations are controlled by physiological mechanisms that respond to *density*. He presented evidence showing that as numbers of animals in a given area increase, stress builds up until it triggers an endocrine reaction that acts to collapse the population.

Christian needed more data and had been looking for a chance to study a mammalian population in the actual process of collapsing. The ideal situation would be one in which endocrine studies could be made before, during, and after collapse. Fortunately, the buildup of the population of the James Island deer came to his attention before it was too late.

THE DIE-OFF ON JAMES ISLAND

About fourteen miles west of the town of Cambridge, Maryland, and less than a mile out in Chesapeake Bay lies James Island, approximately half a square mile (280 acres) of uninhabited land. In 1916 four or five Sika deer (*Cervus nippon*) were released on the island. Breeding freely, the herd built up steadily until it numbered between 280 and 300, a density of about one deer per acre. At this point, reached in 1955, it was apparent that something would have to give before too long.

In 1955, Christian began his research by shooting five deer for detailed histological studies of the adrenal glands, thymus, spleen, thyroid, gonads, kidneys, liver, heart, lungs, and other tissues. The deer were weighed, the contents of their stomachs recorded, and age, sex, and general condition, as well as the presence or absence of deposits of fat under the skin, in the abdomen, and between the muscles, were noted.

Once these records were made, the observers settled down

to wait. In 1956 and 1957 no change occurred. But in the first three months of 1958, over half of the deer died, and 161 carcasses were recovered. The following year more deer died and another drop took place. The population stabilized at around eighty. Twelve deer were collected for histological study between March 1958 and March 1960.

What was responsible for the sudden death of one hundred ninety deer in a two-year period? It wasn't starvation, because the food supply was adequate. In fact, all of the deer collected were in excellent condition, with shining coats, well-developed muscles, and fat deposits between the muscles.

Carcasses collected between 1959 and 1960 resembled those taken in 1956 and 1957 in every outward respect but one. The deer taken after the population collapse and stabilization were markedly larger in body size than those taken just before and during the die-off. The 1960 bucks averaged 34 per cent heavier than the 1958 bucks. Does taken in 1960 were 28 per cent heavier than the 1955–57 does.

The weight of the adrenal glands of the Sika deer remained constant from 1955 to 1958, during the period of maximum density and die-off. The weight decreased 46 per cent between 1958 and 1960. In immature deer, who formed a large proportion of the casualties, adrenal weight dropped 81 per cent after the die-off. There were also important changes in the cell structure of the adrenals that pointed to great stress, even in the survivors. While two cases of hepatitis were discovered, it was thought that these were a result of decreased resistance to stress due to overactive adrenals. In interpreting Christian's data, it is important to clarify the significance of the adrenal glands. The adrenals play an important part in the regulation of growth, reproduction, and the level of the body's defenses. The size and weight of these important glands is not fixed but responds to stress. When animals are too frequently stressed, the adrenals, in order to meet the emergency, become overactive and enlarged. The enlarged adrenals of characteristic cell structure showing stress were therefore highly significant.

An added factor which undoubtedly contributed to stress was the fact that freezing weather in February of 1958 prevented the deer from swimming to the mainland at night, as

their custom, a journey which afforded at least temporary respite from crowding. The major die-off followed this freeze. Lack of relief from confinement, combined with cold, which is also known to cause stress, may have been the last straw.

Summing up at a symposium on crowding, stress, and natural selection in 1961, Christian stated: "Mortality evidently resulted from shock following severe metabolic disturbance, probably as a result of prolonged adrenocortical hyperactivity, judging from the histological material. There was no evidence of infection, starvation, or other obvious cause to explain the mass mortality."

From the physiological side, Christian's study is complete and leaves nothing to be desired. There are, however, some questions about the behavior of the deer under stress that will remain unanswered until another opportunity presents itself. For example, did they show increased aggression? Was this one reason why about nine-tenths of the casualties during the die-off were does and fawns? Hopefully, it will be possible to have a year-round observer next time.

PREDATION AND POPULATION

Less dramatic, but useful in supplying additional evidence that the Malthusian doctrine cannot account for the majority of mass die-offs, were the late Paul Errington's investigations of predation. Errington found, on examining the stomach contents of owls, that a very high proportion consisted of young, immature, old, or sick animals (which were too slow to escape the predator). In a study of muskrats, he found that more died of disease, apparently as a consequence of lowered resistance due to stress from overcrowding, than were captured by the voracious mink. Twice in one year, muskrats dead of disease were found in one lodge. Errington states that muskrats share with men the propensity of growing savage under stress from crowding. He also shows that crowding past a certain limit results in lowered birth rates for muskrats.

By now, many ethologists have on their own come to the conclusion that the relationship of the predator to his prey is one of subtle symbiosis in which the predator does not con-

trol population but is rather a constant environmental pressure that acts to improve the species. Interestingly enough, little attention is paid to these studies. A recent example has been described in detail by the biologist Farley Mowat, who was sent to the Arctic by the Canadian government to establish the number of caribou killed by wolves. The caribou herds have been dwindling so that the wolves could be exterminated in clear conscience. He found that: (a) the wolves accounted for only a small number of caribou deaths; (b) they were important to the caribou in keeping the herds healthy and strong (a fact which the Eskimo knew all along); and (c) it was the killing of caribou by *hunters and trappers* to feed their dogs in the winter which was decreasing the herds. In spite of the convincing, carefully marshaled evidence which appears in his book, *Never Cry Wolf*, wolves are now being systematically poisoned, according to Mowat. While it is not possible to calculate in advance what the loss of the Arctic wolf will mean, the lesson should not be ignored. This is simply one of the many examples of how shortsighted cupidity can threaten the balance of nature. When the wolves are gone, the caribou will continue to decrease because the hunters will be there. Those that remain will not be kept as strong as before due to removal of the therapeutic pressure formerly provided by the wolves.

The above examples fall into the general category of the natural experiment. What happens when an element of control is introduced and populations of animals are allowed to build up freely with plenty of food but in the absence of predators? The experiments and studies described in the next chapter reveal quite clearly that predation and food supply may be less significant than we think. They document in detail the role of stress from crowding as a factor in population control and provide some insights into the biochemical mechanisms of population control.

III

CROWDING AND SOCIAL BEHAVIOR IN ANIMALS

CALHOUN'S EXPERIMENTS

Anyone driving along a country road outside Rockville, Maryland, in 1958 would hardly have noticed an ordinary stone barn set back from the road. Inside it was far from ordinary, however, for it housed a structure set up by the ethologist John Calhoun to provide for the material needs of several colonies of domesticated white Norway rats. Calhoun wished to create a situation in which it would be possible to observe the behavior of the rat colonies at any time.

Actually, the experiments in the barn represented only the most recent phase of a fourteen-year research program. In March 1947, Calhoun initiated his studies of population dynamics under natural conditions by introducing five pregnant *wild* Norway rats into a quarter-acre outdoor pen. His observations covered twenty-eight months. Even with plenty of food and no pressure from predation, the population never exceeded 200 individuals, and stabilized at 150. The difference between experiments carried out in the laboratory and what happens to wild rats living under more natural conditions is emphasized by these studies. Calhoun makes the point that in the twenty-eight months covered by the study the five female rats could have produced 50,000 progeny. Yet available space could not have accommodated this number. Nevertheless 5000 rats can be kept in a healthy state in 10,000 square feet of space if they are kept in pens two feet square. If the cage size is reduced to eight inches, the 50,000 rats can not only be accommodated but remain healthy. The question

Calhoun posed was, Why did the population level off at 150 in the wild state?

Calhoun discovered that even with 150 rats in a quarter-acre pen fighting was so disruptive to normal maternal care that only a few of the young survived. Furthermore, the rats were not randomly scattered throughout the area, but had organized themselves into twelve or thirteen discrete local colonies of a dozen rats each. He also noted that twelve rats is the maximum number that can live harmoniously in a natural group and that even this number may induce stress with all the physiological side effects described at the end of Chapter II.

The experience gained with the outdoor pen enabled Calhoun to design a set of experiments in which rat populations could build up freely under conditions that would permit detailed observation without influencing the behavior of the rats in relation to each other.

The results of these experiments are sufficiently startling to warrant a detailed description. Alone, they tell us a great deal about how organisms behave under different conditions of crowding, and they throw new light on how the social behavior that accompanies crowding can have significant physiological consequences. Combined with Christian's work mentioned earlier and with hundreds of other experiments and observations on animals ranging from weasels and mice to humans, Calhoun's studies take on added significance.

Calhoun's experiments are unusual because psychologists conducting this type of research traditionally attempt to control or eliminate all except one or two variables which they can then manipulate at will. Also most of their research applies to the responses of individual organisms. Calhoun's experiments, however, dealt with large, reasonably complex groups. By choosing subjects with a short life span, he was able to correct a defect common to group behavior studies —that they usually cover too little time, and thus fail to show the accumulation effect of a given set of circumstances on several generations. Calhoun's methods were in the best tradition of science. Not content with simply one or two sixteen-month runs in which the population was allowed to build up,

he ran six, beginning in 1958 and ending in 1961. The findings of these studies are so varied and so broad in their implications that it is difficult to do justice to them. They should continue to produce new insight for years to come.

Design of the Experiment

Inside his Rockville barn, Calhoun built three 10 by 14-foot rooms open to observation through 3 by 5-foot glass windows cut in the floor of the hayloft. This arrangement permitted observers to have a complete view of the lighted room at any time of the day or night without disturbing the rat. Each room was divided into four pens by electrified partitions. Each pen was a complete dwelling unit, containing a food hopper, a drinking trough, places to nest (skyscraper type burrows for observation), and nesting materials. Ramps over the electrified fence connected all pens but I and IV. These areas then became the end pens of a row of four that had been folded to save space.

The experience with the wild rats had indicated that forty to forty-eight rats could occupy the room. If they were equally divided, each pen would accommodate a colony of twelve rats, the maximum number of a normal group before serious stress from crowding occurs.

To begin his studies, Calhoun placed one or two pregnant females about to give birth in each pen with ramps removed, and allowed the young to mature. A balanced sex ratio was maintained by removing the excess so that his first series began with thirty-two rats, offspring of the five females. Then ramps were replaced and all rats were allowed complete freedom to explore all four pens. The second series began with fifty-six rats, and the mothers were removed upon weaning their young. As in the first series, the connecting ramps were replaced so that the young mature rats could explore all four pens.

From this point on, human intervention ceased except for the removal of surplus infants. This was done in order to prevent the population from exceeding a limit of eighty, twice that at which stress was definitely detectable. Calhoun rea-

soned that if he failed to maintain this safety margin, the colonies would suffer a population collapse, or die-off, similar to that of the Sika deer, from which they would not recover. His strategy was to maintain a population in a stressful situation while three generations of rats were reared, so that he could study the effects of stress not only on individuals but on several generations.

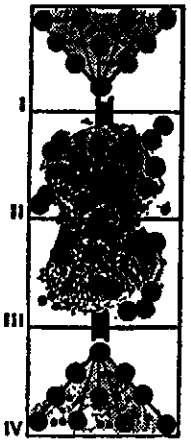
Development of the Sink

The word "sink" is used figuratively to mean a receptacle of foul or waste things. Calhoun invented the term "behavioral sink" to designate the gross distortions of behavior which appeared among the majority of the rats in the Rockville barn. Such a phenomenon, he believes, is "the outcome of any behavioral process that collects animals together in unusually great numbers. The unhealthy connotations of the term are not accidental: a behavioral sink does act to aggravate all forms of pathology that can be found within a group."

The behavioral sink included disruptions of nest building, courting, sex behavior, reproduction, and social organization. Autopsied rats showed serious physiological effects as well.

The sink was reached when the population density was approximately double that which had been observed to produce a maximum of stress in the wild rat colony. The term "density" must be expanded beyond simple ratio of individuals to available space. Except in the most extreme cases, density alone seldom causes stress in animals.

In order to grasp Calhoun's idea, we need to move for the moment to the young rats and follow them from the time they were given freedom to roam the four pens to the time when the sink developed. In the normal uncrowded state, there is a short period when the young but physically mature male rats fight with each other until they establish a fairly stable social hierarchy. In the first of the two Rockville series described here, two dominant male rats established territories in Pens I and IV. Each maintained a harem of eight to ten females, so that his colony was balanced and consistent with the natural grouping among rats as observed in the quarter-acre pen. The remaining fourteen male rats distributed themselves in Pens II and III. As the population built up to sixty or more, the chances of a rat's being able to eat by himself were minimal. This was because food hoppers had been so designed that food pellets behind a wire screen took a long time to extract. The rats in Pens II and III became conditioned, therefore, to eating with other rats. Calhoun's observations revealed that *when activity built up in the middle pens so that the food hoppers were used from three to five times more frequently than the end pens, the sink began to develop.* Normal patterns of behavior were disrupted as follows.



Courting and Sex

Courting and sex in the Norway rat normally involve a fixed sequence of events. Male rats have to be able to make three basic distinctions in the selection of a mate. First, they have to make the usual male-female distinction and be able to tell the difference between mature and immature individuals. Then they must find a female in a receptive (oestrous) state. When this combination appears within his visual and olfactory field, the male rat chases the female. She runs, but not too fast, and ducks down into the burrow, turns around and sticks her head up to watch the male. He runs around the opening of the burrow and performs a little dance. When the dance is over, the female leaves the burrow and mounting takes place. During the sex act, the male will grasp the skin on the female's neck gently between his teeth.

When the sink developed in Pens II and III, everything changed. Several different categories of males could be identified:

1. The aggressively dominant, of whom there might be as many as three, exhibited normal behavior.
2. The passive males avoided both fighting and sex.

3. The hyperactive subordinate males spent their time chasing females. Three or four might be tailing one harassed female at the same time. During the pursuit phase, they would fail to observe the amenities; instead of stopping at the "burrow" entrance they would follow the female inside so that she had no respite. During mounting, these male rats frequently maintained their grasp on females for several minutes instead of the usual two or three seconds.

4. Pansexual males tried mounting anything; receptive and non-receptive females, males and females alike, young and old. Any sex partner would do.

5. Some males withdrew from social and sexual intercourse and went abroad chiefly at the time when other rats slept.

Nest Building

Both male and female rats participate in building but the female does most of the work. Nesting material is carried into the burrow, piled up, and hollowed out to form a cavity to hold the young. In the Rockville study, females from the "harems" in Pens I and IV and others who had not reached the sink stage were "good housekeepers"; they were neat and kept the area around the nest picked up. Sink females in II and III often failed to complete the nest. They could be seen carrying a piece of nesting material up a ramp and suddenly dropping it. Material that reached the nest was either dropped in the general area or added to a pile that was never hollowed out, so that the young became scattered at birth and few survived.

Care of the Young

Normally, females work hard to keep litters sorted out and if a strange pup was introduced into the nest, the female would remove it. When nests were uncovered, the young would be moved to a new location that was more protected. Sink mothers in the Rockville study failed to sort out the young. Litters became mixed; the young were stepped on and often eaten by hyperactive males who invaded the nests. When a nest was exposed, the mother would start moving the

young but would fail to complete some phase of the move. Young carried outside to another nest were often dropped and eaten by other rats.

Territoriality and Social Organization

The Norway rat has evolved a simple social organizational pattern that calls for living in groups of ten to twelve hierarchically graded individuals occupying a common territory which they defend. The group is dominated by one mature male and is made up of varying proportions of both sexes. High-ranking rats do not have to defer to other rats as much as low-ranking rats. Their status is indicated in part by those areas within the territory which are open to them. The higher the status, the greater the number of areas they may visit.

Dominant male rats in the sink, unable to establish territories, substituted time for space. Three times daily there was a tempestuous "changing of the guard" around the eating bins that was characterized by fighting and scuffling. Each group was dominated by a single male. These three males were equal to each other in rank, but unlike normal hierarchies, which are extraordinarily stable in nature, social rank in the sink was very unstable. "At regular intervals during the course of their working hours, these top-ranking males engaged in free-for-alls that culminated in the transfer of dominance from one male to another."

Another social manifestation was what Calhoun called "classes" of rats, which shared territories and exhibited similar behavior. The function of the class, apparently, is to reduce friction between the rats. Normally, there were as many as three classes in a colony.

An increase in population density leads to a proliferation of classes and subclasses. The hyperactive males violated not only the mating mores by invading the burrow when chasing females, but other territorial mores as well. They ran around in a pack, pushing, probing, exploring, testing. Apparently they were afraid only of the dominant male sleeping at the foot of the ramp in the Pen I or IV area, protecting his territory and his harem against all comers.

The advantages to both the species and the individual be-

stowed by territoriality and stable hierarchical relationships were clearly demonstrated by the rats who occupied Pen I. From the observation window in the top of the room, one could look down and see a large, healthy rat asleep at the foot of a ramp. At the top of the ramp, a small group of hyperactive males might be testing him to see if they could enter. He needed only to open an eye to discourage invasion.

From time to time, one of the females would emerge from a burrow, cross in front of the sleeping male, scamper up the ramp without awakening him, and return later, followed by a pack of hyperactive males who would stop when they reached the top of the ramp. Beyond this point she would not be molested and could bear and rear her young undisturbed by the constant turmoil of the sink. Her measured record of achievement as a mother was ten to twenty-five times that of females in the sink. Not only did she bear twice as many young, but half or better of her young would survive weaning.

Physiological Consequences of the Sink

As with the Sika deer, the sink hit hardest at the female rats and the young. The mortality rate of females in the sink was three and a half times that of the males. Of the 558 young born at the height of the sink, only one-fourth survived to be weaned. Pregnant rats had trouble continuing pregnancy. Not only did the rate of miscarriages increase significantly, but the females started dying from disorders of the uterus, ovaries, and fallopian tubes. Tumors of the mammary glands and sex organs were identified in autopsied rats. The kidneys, livers, and adrenals were also enlarged or diseased and showed signs that are usually associated with extreme stress.

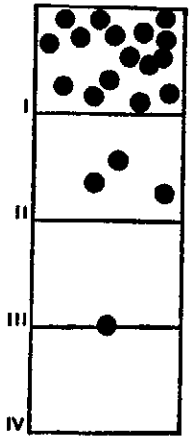
Aggressive Behavior

As Konrad Lorenz, the German ethologist, has made clear in *Man Meets Dog,* normal aggressive behavior has accompanying signals that will extinguish the aggressive impulse when the vanquished has "had enough." Male rats in the sink failed to suppress aggression in each other, and engaged in

very extensive, often unprovoked and unpredictable tail biting. This behavior went on for about three months, until the mature rats discovered new ways to suppress tail biting in their fellows. But young rats, who had not learned how to keep their tails from being bitten, were still subject to extensive damage.

The Sink that Didn't Develop

A second series of experiments demonstrated the strategic relationship between the sink and the conditioned need to eat with other rats. In these experiments, Calhoun changed the type of food from pellet to meal, so that food could be eaten quickly. Water, on the other hand, was dispensed from a slow fountain so that rats became conditioned to drinking instead of eating with other rats. This change kept the population more evenly distributed among the pens; because rats normally drink immediately after awakening, they tended to stay in their sleeping area. (For the previous experiment most of the rats had moved to the pen where they ate.) There is some indication that in the second series, a sink would eventually have developed, but for different reasons. One male took over Pens III and IV, driving all other rats out. A second male was in the process of establishing territorial rights to Pen II. When the experiment was terminated, *80 per cent of the males were concentrated in Pen I, the remainder, minus one, were in Pen II.*



Summary of Calhoun's Experiments

It is clear from Calhoun's experiments that even the rat, hardy as he is, cannot tolerate disorder and that, like man, he needs some time to be alone. Females on the nest are particularly vulnerable, as are the young who need to be screened from birth to weaning. Also, if pregnant rats are harassed

too much, they have increased difficulty in bringing pregnancy to full term.

Probably there is nothing pathological in crowding per se that produces the symptoms that we have seen. Crowding, however, disrupts important social functions and so leads to disorganization and ultimately to population collapse or large-scale die-off.

The sex mores of the rats in the sink were disrupted, and pansexuality and sadism were endemic. Rearing the young became almost totally disorganized. Social behavior of the males deteriorated, so that tail biting broke out. Social hierarchies were unstable, and territorial taboos were disregarded unless backed by force. The extremely high mortality rates of females unbalanced the sex ratio and thus exacerbated the situation of surviving females, who were even more harassed by males during the time they came in heat.

Unfortunately, there is no comparable data on wild rat populations under extreme stress and in the process of collapse with which to compare Calhoun's studies. It is possible, however, that if he had run his studies longer the sink effect would have built up to crises proportions. In fact, Calhoun's evidence certainly points to an imminent crisis. No matter how they are viewed, the rat experiments were both dramatic and complex. Yet it is doubtful that the many interacting factors which combine to maintain a proper population balance could be identified from observations of the white Norway rats alone. Fortunately, however, observation of other species has shed light on the processes by which animals regulate their own density as a function of self-preservation.

THE BIOCHEMISTRY OF CROWDING

How can crowding produce the dramatic results—ranging from aggression through various forms of abnormal behavior to mass die-off—which we have seen in animals as different as the deer, the stickleback, and the rat? Search for answers to this question has produced insights with wide implications.

Two English researchers, A. S. Parkes and H. M. Bruce, who were investigating the differing effects of visual and olfac-

tory stimulation on birds and mammals, reported in *Science* that pregnancy in a mouse is suppressed by the presence of a male mouse other than the original mate during the first four days after conception. At first, the second stud males were allowed to mate with the females during the period of vulnerability. Later it was demonstrated that the mere presence of a second male in the cage would block pregnancy. Finally, it was found that blocking would occur if a pregnant female were introduced into an area from which a male had been recently removed. Since the male was no longer present to be seen by the vulnerable female, it was obvious that smell rather than sight was the active agent. This assumption was proved when it was demonstrated that destruction of the olfactory lobe in the brain of the female mouse rendered her invulnerable to the pregnancy-blocking capacity of the strange male.

Autopsies of the females whose pregnancies were blocked showed that the corpus luteum, which holds the fertilized egg to the wall of the uterus, had failed to develop. Normal formation of the corpus luteum is stimulated by a hormone, prolactin, and pregnancy blockage can be prevented by injecting ACTH.

Exocrinology

Through their work Parkes and Bruce have radically modified prevailing theories of the relationship of the body's delicately balanced chemical control systems to the external world. The ductless, or endocrine, glands have an influence on virtually everything the body does and have long been thought of as a closed system sealed in the body which is only indirectly linked to the outside world. Parkes' and Bruce's experiments demonstrated that this is not always the case. They coined the term "exocrinology" (as contrasted with endocrinology) to express the expanded view of the chemical regulators to include the products of odoriferous glands scattered about the bodies of mammals. Odoriferous substances are secreted from special glands anatomically situated in a variety of spots such as between the hoofs of deer, below the eyes of antelope, on the soles of the feet of mice,

on the back of the head of the Arabian camel, and in the armpits of man. In addition, odoriferous substances are produced by the genitalia and appear in the urine and feces.

It is now recognized that the external secretions of one organism work directly on the body chemistry of other organisms and serve to help integrate the activities of populations or groups in a variety of ways. Just as the internal secretions integrate the individual, external secretions aid in integrating the group. The fact that the two systems are interlinked helps to explain in part the self-regulating nature of population controls and the abnormal behavior which follows excessive crowding. One syndrome revolves around bodily responses to stress.

Hans Selye, an Austrian working in Ottawa, whose name has long been associated with studies of stress, demonstrated that animals can die from shock if they are repeatedly stressed. Any increased demand on the organism must be met by the addition of energy. In mammals this source of energy is blood sugar. If repeated demands exhaust the supply of sugar available, the animal goes into shock.

The Sugar-Bank Model

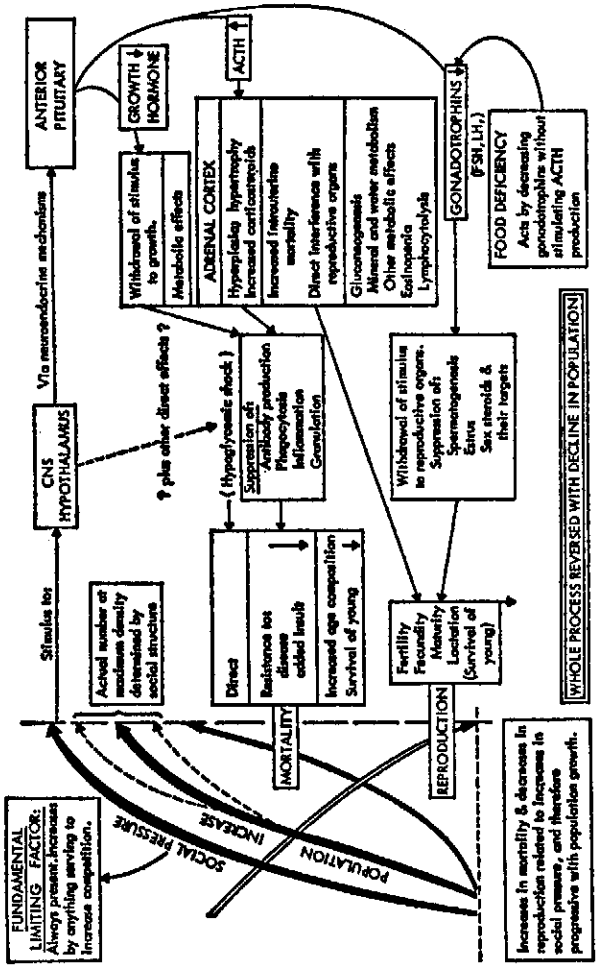
Under the intriguing title "The Hare and the Haruspex," Yale biologist Edward S. Deevey recently explained the biochemistry of stress and shock in an effective metaphor:

> It is possible to speak of vital needs as payable in sugar, for which the liver acts as a bank. Routine withdrawals are smoothly handled by hormones from the pancreas and from the adrenal medulla, which act as paying tellers; but the top-level decisions (such as whether to grow or reproduce) are reserved for the bank's officers, the adrenal cortex and pituitary glands. Stress, in Selye's view, amounts to an administrative flap among the hormones, and shock results when the management overdraws the bank.
>
> If the banking model is gently dissected, it reveals its first and most important servomechanism: a remarkably bureaucratic hook-up between the adrenal cortex, acting as cashier's office, and the pituitary, as board of directors. Injury and infection are common forms of stress, and in directing controlled inflammation to combat them the cortex draws cashier's checks on the liver. If the stress persists, a hormone called cortisone sends a worried message to the pituitary. Preoccupied with the big picture, the pituitary delegates a vice-presidential type, ACTH, or adrenocorticotropic hormone, whose role is literally to buck up the adrenal cortex. As students of Parkinson would predict, the cortex, bucked, takes on more personnel, and expands its activities, including that of summoning more ACTH. The viciousness of the impending spiral ought to be obvious, and ordinarily it is; but while withdrawals continue, the amount of sugar in circulation is deceptively constant (the work of another servomechanism) and there is no device, short of autopsy, for taking inventory at the bank.
>
> If the pituitary is conned by persisting stress into throwing more support to ACTH, the big deals begin to suffer retrenchment. A cutback of ovarian hormone, for instance, may allow the cortex to treat a well-started foetus as an inflammation to be healed over. Likewise, the glandular sources of virility and of maternity, though unequally prodigal of sugar, are equally likely to dry up. Leaving hypertension aside (because it involves another commodity, salt, which needn't be gone into just now), the fatal symptom can be hypoglycemia. A tiny extra stress, such as a loud noise . . . corresponds to an unannounced visit by the bank examiner: The adrenal medulla is startled into sending a jolt of adrenalin to the muscles, the blood is drained of sugar, and the brain is suddenly starved. This, incidentally, is why shock looks like hyperinsulinism. An overactive pancreas, like a panicky adrenal, resembles an untrustworthy teller with his hand in the till.

The Adrenals and Stress

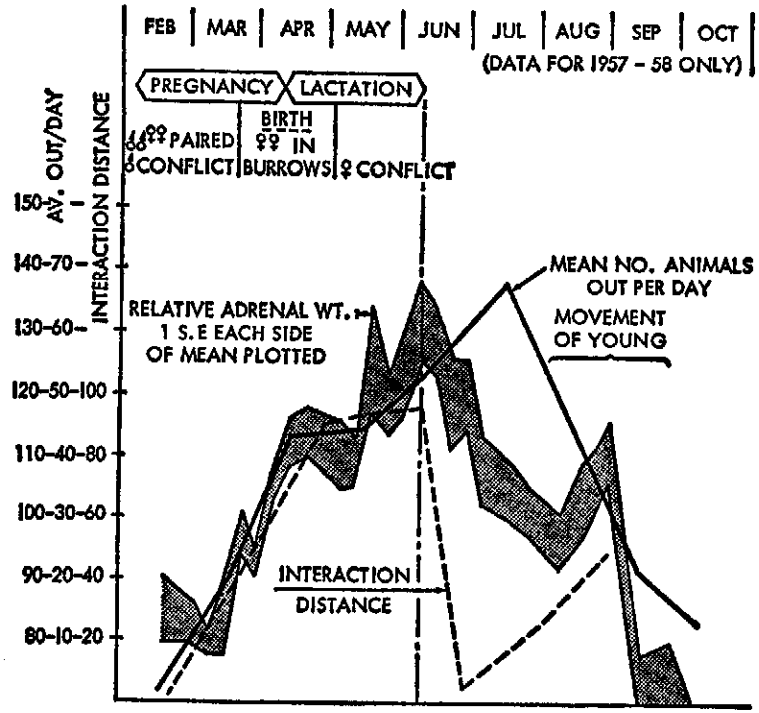
The reader will remember that the Sika deer showed greatly enlarged adrenal glands just before and during the die-off. This increase in size was presumably associated with increased demands for ACTH, which were due to increased stress from crowding.

Following this lead, Christian in the late 1950s made a study of seasonal changes in the adrenal glands of wood-



The Biochemistry of Population Control Christian's original (1961) chart showing how endocrine feedback mechanisms lower fertility and decrease resistance to disease in response to population buildup. Note that the process is reversed as population declines. For further explanation see Edward S. Deevey's quote in text under "The Sugar-Bank Model."

chucks. Among the 872 animals collected and autopsied over a four-year period, the mean weight of the adrenals increased as much as 60 per cent from March to the end of June, a period when the male woodchucks were competing for mates, were active for longer portions of the day, and *more of them were concentrated in a given area at the same time.* Adrenal weight declined in July, when the greatest number of animals were active but *aggressiveness* was very low. The weight rose again sharply in August, when there was exten-



Christian's chart (1963) showing seasonal changes in the weight of woodchuck adrenals in relation to the number of animals. Note how population builds up from March through June accompanied by decreased interaction distance, conflict, stress, and an increase in the weight of the adrenals. Conflicts during the breeding season exacerbate stress. In July, as the young move out, the interaction distance increases and the endocrines return to normal.

sive movement among young woodchucks moving out to establish territories and there were frequent conflicts. Thus, concluded Christian, "it seems that the lack of aggressiveness was the most important consideration initiating the summer decline in adrenal weight."

It is now widely held that the processes of selection which control evolution favor the dominant individuals in any given group. Not only are they under less stress but they also seem to be able to stand more stress. Christian, in a study of the "pathology of overpopulation" showed that the adrenals work harder and become more enlarged in subordinate than in dominant animals. Also, his own studies had demonstrated that there is a relationship between aggressiveness and distance between animals. When aggressiveness was high among male woodchucks during the breeding season, the mean interaction distance between animals increased. The mean weight of the adrenals was correlated with the mean interaction distance, as well as with the number of interactions.

In other words, to paraphrase Christian, when aggressiveness increases, animals need more space. If no more space is available, as occurs when populations are approaching a maximum, a chain reaction is started. A blowup of aggressiveness and sexual activity and accompanying stresses overload the adrenals. The result is a population collapse due to lowering of the fertility rate, increased susceptibility to disease, and mass mortality from hypoglycemic shock. In the course of this process, the dominant animals are favored and usually survive.

The late Paul Errington, a gifted ethologist and professor of zoology at Iowa State University, spent years observing the effects of crowding on marsh muskrats. He came to the conclusion that if collapse were too severe the recovery time was immeasurably prolonged. The English investigator H. Shoemaker showed that the effects of crowding could be very considerably counteracted by providing the right kind of space for certain critical situations. Canaries which he crowded into a single large cage worked out a dominance hierarchy which interfered with nesting of low-ranking birds until they were provided with small cages where pairs could nest and rear

their young. The lower-ranking male canaries thus had an inviolate territory of their own and were therefore more successful in producing a brood than they otherwise would have been.

The provision of individual territories for families and the screening of animals from each other at critical times during the mating season can counteract the ill effects of crowding down to and including animals as low on the evolutionary scale as the stickleback.

The Uses of Stress

If we tend to deplore the results of crowding, we should not forget that the stress which it produces has had positive values. Such stress has been an efficient device in the service of evolution, because it employs the forces of *intra*species competition rather than the *inter*species competition which is more familiar to most of us as nature "red in tooth and claw."

There is a very important difference between these two evolutionary pressures. Competition between species sets the stage on which the first types can develop. It involves whole species, rather than different strains of the same animal. Competition within a species, on the other hand, refines the breed and enhances its characteristic features. In other words, intraspecies competition serves to enhance the organism's incipient form.

Present assumptions about the evolution of man illustrate the effects of both pressures. Originally a ground-dwelling animal, man's ancestor was forced by interspecies competition and changes in the environment to desert the ground and take to the trees. Arboreal life calls for keen vision and decreases dependence on smell, which is crucial for terrestrial organisms. Thus man's sense of smell ceased to develop and his powers of sight were greatly enhanced.

One consequence of the loss of olfaction as an important medium of communication was an alteration in the relationship between humans. It may have endowed man with greater capacity to withstand crowding. If humans had noses like rats, they would be forever tied to the full array of emotional shifts occurring in persons around them. Other people's

anger would be something we could smell. The identity of anyone visiting a home and the emotional connotations of everything that took place in the home would be matters of public record so long as the smell persisted. The psychotic would begin to drive all of us mad, and the anxious would make us even more anxious. To say the least, life would be much more involved and intense. It would be less under conscious control, because the olfactory centers of the brain are older and more primitive than the visual centers.

The shift from reliance on the nose to reliance on the eye as a result of environmental pressures has completely redefined the human situation. Man's ability to plan has been made possible because the eye takes in a larger sweep; it codes vastly more complex data and thus encourages thinking in the abstract. Smell, on the other hand, while deeply emotional and sensually satisfying, pushes man in just the opposite direction.

Man's evolution has been marked by the development of the "distance receptors"—sight and hearing. Thus he has been able to develop the arts which employ these two senses to the virtual exclusion of all the others. Poetry, painting, music, sculpture, architecture, the dance depend primarily though not exclusively on eyes and ears. So do the communications systems which man has set up. In later chapters, we shall see how the differing emphasis laid on sight, hearing, and smell by cultures which man has developed has led to greatly differing perceptions of space and the relations of individuals in space.

IV

PERCEPTION OF SPACE: DISTANCE RECEPTORS—EYES, EARS, AND NOSE

. . . we can never be aware of the world as such, but only of . . . the impingement of physical forces on the sensory receptors.

F. P. KILPATRICK
Explorations in Transactional Psychology

Study of the ingenious adaptations displayed in the anatomy, physiology, and behavior of animals leads to the familiar conclusion that each has evolved to suit life in its particular corner of the world . . . each animal also inhabits a private subjective world that is not accessible to direct observation. This world is made up of information communicated to the creature from the outside in the form of messages picked up by its sense organs.

H. W. LISSMAN
"Electric Location by Fishes,"
Scientific American

These two statements pinpoint the importance of the receptors in constructing the many different perceptual worlds that all organisms inhabit. The statements also emphasize that the differences in these worlds cannot be ignored. In order to understand man, one must know something of the nature of his receptor systems and how the information received from these receptors is modified by culture. Man's sensory apparatus falls into two categories, which can be roughly classified as:

1. The distance receptors—those concerned with examination of distant objects—the eyes, the ears, and the nose.
2. The immediate receptors—those used to examine the world close up—the world of touch, the sensations we receive from the skin, membranes, and muscles.

This classification can be broken down even further. The skin, for example, is the chief organ of touch and is also sensitive to heat gain and loss; both radiant and conducted heat are detected by the skin. Hence, strictly speaking, the skin is both an immediate and a distance receptor.

There is a general relationship between the evolutionary age of the receptor system and the amount and quality of information it conveys to the central nervous system. The tactile, or touch, systems are as old as life itself; indeed, the ability to respond to stimuli is one of the basic criteria of life. Sight was the last and most specialized sense to be developed in man. Vision became more important and olfaction less essential when man's ancestors left the ground and took to the trees, as I mentioned in the last chapter. Stereoscopic vision is essential in arboreal life. Without it, jumping from branch to branch becomes very precarious.

VISUAL AND AUDITORY SPACE

The amount of information gathered by the eyes as contrasted with the ears has not been precisely calculated. Such a calculation not only involves a translation process, but scientists have been handicapped by lack of knowledge of what to count. A general notion, however, of the relative complexities of the two systems can be obtained by comparing the size of the nerves connecting the eyes and the ears to the centers of the brain. Since the optic nerve contains roughly eighteen times as many neurons as the cochlear nerve, we assume it transmits at least that much more information. Actually, in normally alert subjects, it is probable that the eyes may be as much as a thousand times as effective as the ears in sweeping up information.

The area that the unaided ear can effectively cover in the course of daily living is quite limited. Up to twenty feet the ear is very efficient. At about one hundred feet, one-way vocal communication is possible, at somewhat slower rate than at conversational distances, while two-way conversation is very considerably altered. Beyond this distance, the auditory cues with which man works begin to break down rapidly.

The unaided eye, on the other hand, sweeps up an extraordinary amount of information within a hundred-yard radius and is still quite efficient for human interaction at a mile.

The impulses that activate the ear and the eye differ in speed as well as in quality. At temperatures of 0°C. (32°F.) at sea level, sound waves travel *1100 feet a second* and can be heard at frequencies of 50 to 15,000 cycles per second. Light rays travel *186,000 miles a second* and are visible at frequencies of 10,000,000,000,000,000 cycles per second.

The type and complexity of the instruments used to extend the eye and the ear indicate the amount of information handled by the two systems. Radio is much simpler to build and was developed long before television. Even today, with our refined techniques for extending man's senses, there is a great difference in the quality of the reproductions of sound and vision. It is possible to produce a level of audio fidelity that exceeds the ability of the ear to detect distortion, whereas the visual image is little more than a moving reminder system that has to be translated before it can be interpreted by the brain.

Not only is there a great difference in the amount and type of information that the two receptor systems can process, but also in the amount of space that can be probed effectively by these two systems. A sound barrier at a distance of a quarter of a mile is hardly detectable. This would not be true of a high wall or screen that shuts out a view. Visual space, therefore, has an entirely different character than auditory space. Visual information tends to be less ambiguous and more focused than auditory information. A major exception is the hearing of a blind person who learns to selectively attend the higher audio frequencies which enable him to locate objects in a room.

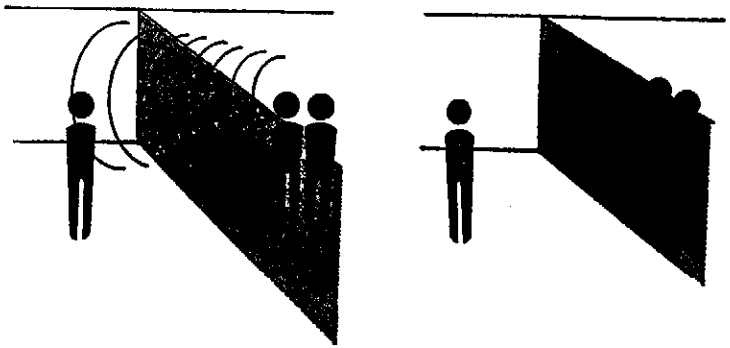
Bats, of course, live in a world of focused sound which they produce like radar, enabling them to locate objects as small as a mosquito. Dolphins, too, use very high-frequency sound rather than sight to navigate and locate food. It should be noted that sound travels four times as fast in water as it does in air.

What is not known technically is the effect of incongruity between visual and auditory space. Are sighted people more likely to stumble over chairs in reverberating rooms, for ex-

ample? Is it easier to listen to someone else if his voice is coming from one readily located spot instead of from several loudspeakers as is characteristic of our P.A. systems? There is some data, however, on auditory space as a factor in performance. A study by J. W. Black, a phonetician, demonstrated that the size and reverberation time of a room affects reading rates. People read more slowly in larger rooms where the reverberation time is slower than they do in smaller rooms. One of my own interview subjects, a gifted English architect, perspicaciously improved the performance of a malfunctioning committee by bringing in line the auditory and visual worlds of the conference chamber. There had been so many complaints about the inadequacy of the chairman that a replacement was about to be requested. The architect had reason to believe that there was more in the environment than in the chairman to explain the difficulties. Without telling his subjects what he was doing, the architect managed to retain the chairman while he corrected environmental faults. The meeting room was next to a busy street whose traffic noises were intensified by reverberations from the hard walls and rugless floors inside. When reduction of the auditory interference made it possible to conduct a meeting without undue strain, complaints about the chairman ceased.

It should be noted here by way of explanation that the capacity of the "public school" upper-class English to direct and modulate the voice is far greater than that of Americans. The annoyance the English experience when acoustic interference makes it difficult to direct the voice is very great indeed. One sees the sensitivity of the English to acoustic space in Sir Basil Spence's successful recreation of the *atmosphere* of the original Coventry cathedral (destroyed during the blitz) while using a new and visually daring design. Sir Basil felt that a cathedral should not only look like a cathedral but should sound like one as well. Choosing the cathedral at Durham as a model, he tested literally hundreds of samples of plaster until he found one that had all the desired acoustic qualities.

Space perception is not only a matter of what can be perceived but what can be screened out. People brought up in different cultures learn as children, without ever knowing that they have done so, to screen out one type of information while paying close attention to another. Once set, these perceptual patterns apparently remain quite stable throughout life. The Japanese, for example, screen visually in a variety of ways but are perfectly content with paper walls as acoustic screens. Spending the night at a Japanese inn while a party is going on next door is a new sensory experience for the Westerner. In contrast, the Germans and the Dutch depend on thick walls and double doors to screen sound, and have difficulty if they must rely on their own powers of concentration to screen out sound. If two rooms are the same size and one screens out sound but the other one doesn't, the sensitive German who is trying to concentrate will feel less crowded in the former because he feels less intruded on.



OLFACTORY SPACE

In the use of the olfactory apparatus Americans are culturally underdeveloped. The extensive use of deodorants and the suppression of odor in public places results in a land of olfactory blandness and sameness that would be difficult to duplicate anywhere else in the world. This blandness makes for undifferentiated spaces and deprives us of richness and variety in our life. It also obscures memories, because smell evokes much deeper memories than either vision or sound. Since the American experience of smell is so poorly developed, it seems useful to review briefly the function of olfaction as a biological activity. Here is a sense that must have per-

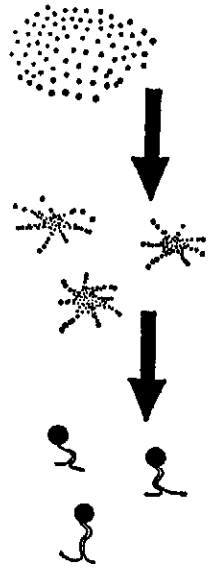
formed important functions in our past. Hence it is pertinent to ask what roles it did perform and whether some of these are still not relevant, although ignored or even suppressed by our culture.

The Chemical Basis of Olfaction

Odor is one of the earliest and most basic methods of communication. It is primarily chemical in nature and it is referred to as the chemical sense. Serving diverse functions it not only differentiates individuals but makes it possible to identify the emotional state of other organisms. It aids in locating food and helps stragglers to find or follow the herd or the group as well as providing a means of marking territory. Smell betrays the presence of an enemy and may even be used defensively, as in the case of the skunk. The powerful effect of sexual odors is known to anyone who has lived in the country and observed how a bitch in heat will draw dogs for miles around. Other animals have a similarly well-developed olfactory sense. Consider the silk moth, which can locate its mate at a distance of two to three miles, or the cockroach, which also has a phenomenal sense of smell. The equivalent of only thirty molecules of the female sex attractant will excite the male cockroach and make him raise his wings and attempt to copulate. In general, smells are enhanced in dense media, such as sea water, and do not work as well in thin media. Smell is apparently the means that salmon use to return across thousands of miles of ocean to the stream where they were spawned. Olfaction gives way to sight when the medium thins out as it does in the sky. (It would not be effective for a soaring hawk trying to find a mouse a thousand feet below.) Although com-

munication of various types is a major function of smell, it is not popularly conceived of as a signal or message system. And it is only recently that the interrelationship between olfaction (exocrinology) and chemical regulators in the body (endocrinology) has become known.

On the basis of a long history of the study of internal regulators it is known that chemical communication is most suited to the releasing of highly selective responses. Thus chemical messages in the form of hormones work on specific cells programmed to respond in advance while other cells in the immediate vicinity are unaffected. The functioning of the endocrine system in response to stress has been noted in the two preceding chapters. In fact, it would be impossible for advanced organisms to live at all if the highly developed chemical message systems of the body were not working twenty-four hours a day to balance performance with requirements. The body's chemical messages are so complete and specific that they can be said to far exceed in organization and complexity any of the communication systems man has yet created as extensions. This includes language of all forms—spoken, written, or mathematical—as well as the manipulation of various kinds of information by the most advanced computers. The chemical information systems of the body are sufficiently specific and exact to reproduce that body perfectly and keep it operating under a wide range of contingencies.



As we saw in the preceding chapter, Parkes and Bruce demonstrated the fact that, at least under certain circumstances, the endocrine system of one mouse was deeply involved with that of another, and that *olfaction constituted the principal information channel.* There are additional instances, both higher and lower on the evolutionary scale, in which chemical communication constitutes an important, and sometimes the sole, means of integrating behavior. This occurs even on the most elementary levels of life. An amoeba (*Dictyostelium discoideum*),

which begins life as a single-celled microscopic organism, maintains a uniform distance from its neighbors by chemical means. As soon as the food supply dwindles, the amoebae, using a chemical locator called acrasin, aggregate into a slug that forms into a stalk ending in a small, round, fruiting body of spores at the top. Discussing "action at a distance" and how these social amoebae are oriented in space, the biologist Bonner, quoted in John Tyler's "How Slime Molds Communicate," *Scientific American,* August 1963, states:

> We were not at the time worrying about what the cells say to one another in the process of marshaling a unified multicellular organism. We had become interested in what might be termed conversations between cell masses and their neighbors. We had raised the level of discourse, in other words, from that of cells to that of organisms composed of numbers of cells. It now appears that the same principle of communication is engaged at both levels.

Bonner and his colleagues demonstrated that the social aggregations of amoebae are evenly spaced. The spacing mechanism is gas, produced by the colony, which blocks overconcentration by maintaining a population density with a ceiling of two hundred fifty cells per cubic millimeter of air space. Bonner was able to increase the density experimentally by placing activated charcoal near colonies of cells. The charcoal absorbed the gas and the population density shot up accordingly, thus demonstrating one of the simplest and most basic of all of the population control systems.

Chemical messages can be of many kinds. Some of them even act across time to warn succeeding individuals when something has happened to a predecessor. Hediger tells how reindeer, approaching a spot where one of their species has recently been frightened, will flee when they smell the scent excreted from the hoof glands of the frightened deer. Hediger also cites experiments by von Frisch, who found that a fluid extract of the crushed skin of a minnow will cause flight reaction in members of the same species. In discussing olfactory messages with a psychoanalyst, a skillful therapist with an unusual record of success, I learned that the therapist could

clearly distinguish the smell of anger in patients at a distance of six feet or more. People who work with schizophrenics have long claimed that they have a characteristic odor. Such naturalistic observations led to a series of experiments in which Dr. Kathleen Smith, a St. Louis psychiatrist, demonstrated that rats readily distinguish between the smell of a schizophrenic and a non-schizophrenic. In light of the powerful effect of chemical message systems one wonders if fear, anger, and schizophrenic panic may not act directly on the endocrine systems of nearby persons. One would suspect that this would be the case.

Olfaction in Humans

Americans traveling abroad are apt to comment on the smell of strong colognes used by men living in Mediterranean countries. Because of their heritage of northern European culture, these Americans will find it difficult to be objective about such matters. Entering a taxicab, they are overwhelmed by the inescapable presence of the driver, whose olfactory aura fills the cab.

Arabs apparently recognize a relationship between disposition and smell. The intermediaries who arrange an Arab marriage usually take great precautions to insure a good match. They may even on occasion ask to smell the girl and will reject her if she "does not smell nice," not so much on esthetic grounds but possibly because of a residual smell of anger or discontent. Bathing the other person in one's breath is a common practice in Arab countries. The American is taught not to breathe on people. He experiences difficulty when he is within olfactory range of another person with whom he is not on close terms, particularly in public settings. He finds the intensity and sensuality overwhelming and has trouble paying attention to what is being said and at the same time coping with his feelings. In brief, he has been placed in a double bind and is pushed in two directions at once. The lack of congruence between U.S. and Arab olfactory systems affects both parties and has repercussions which extend beyond mere discomfort or annoyance. Chapter XII, dealing with the contact of U.S. and Arab culture, will explore these

points further. By banishing all but a few odors from our public life, what have Americans done to themselves and what effect does this have on life in our cities?

In the northern European tradition most Americans have cut themselves off from a powerful communication channel: olfaction. Our cities lack both olfactory and visual variety. Anyone who has walked along the streets of almost any European village or town knows what is nearby. During World War II in France I observed that the aroma of French bread freshly removed from the oven at 4:00 A.M. could bring a speeding jeep to a screaming halt. The reader can ask himself what smells we have in the U.S. that can achieve such results. In the typical French town, one may savor the smell of coffee, spices, vegetables, freshly plucked fowl, clean laundry, and the characteristic odor of outdoor cafés. Olfactions of this type can provide a sense of life; the shifts and the transitions not only help to locate one in space but add zest to daily living.

V

PERCEPTION OF SPACE: IMMEDIATE RECEPTORS—SKIN AND MUSCLES

Much of Frank Lloyd Wright's success as an architect was due to his recognition of the many different ways in which people experience space. The old Imperial Hotel in Tokyo provides the Westerner with a constant visual, kinesthetic, and tactile reminder that he is in a different world. The changing levels, the circular, walled-in, intimate stairs to the upper floors, and the small scale are all new experiences. The long halls are brought to scale by keeping the walls within reach. Wright, an artist in the use of texture, used the roughest of bricks, then separated them by smooth, gilded mortar set in from the surface a full half-inch. Walking down these halls the guest is almost compelled to run his fingers along the grooves. But Wright did not intend that people run their fingers along the grooves. The brick is so rough that to obey this impulse would be to risk mangling a finger. With this device Wright enhances the experience of space by personally involving people with the surfaces of the building.

The early designers of the Japanese garden apparently understood something of the interrelationship between the kinesthetic experience of space and the visual experience. Lacking wide-open spaces, and living close together as they do, the Japanese learned to make the most of small spaces. They were particularly ingenious in stretching visual space by exaggerating kinesthetic involvement. Not only are their gardens designed to be viewed with the eyes, but more than the usual number of muscular sensations are built into the experience of walking through a Japanese garden. The visitor is periodically forced to watch his step as he picks his way along ir-

regularly spaced stepstones set in a pool. At each rock he must pause and look down to see where to step next. Even the neck muscles are deliberately brought into play. Looking up, he is arrested for a moment by a view that is broken as soon as he moves his foot to take up a new perch. In the use of interior space, the Japanese keep the edges of their rooms clear because everything takes place in the middle. Europeans tend to fill up the edges by placing furniture near or against walls. As a consequence, Western rooms often look less cluttered to the Japanese than they do to us.

Both the Japanese and the European concept of spatial experience varies from our own, which is much more limited. In America, the conventional idea of the space needed by office employees is restricted to the actual space required to do the job. Anything beyond the minimum requirement is usually regarded as a "frill." The concept that there may be additional requirements is resisted, at least in part because of the American's mistrust of subjective feelings as a source of data. We can measure with a tape whether or not a man can reach something, but we must apply an entirely different set of standards to judge the validity of an individual's feeling of being cramped.

HIDDEN ZONES IN AMERICAN OFFICES

Because there is so little information on what it is that produces these subjective feelings, I conducted a series of "nondirected" interviews on people's reactions to office space. These interviews revealed that the single most important criterion is what people can do in the course of their work without bumping into something. One of my subjects was a woman who had occupied a series of offices of different dimensions. Doing the same job in the same organization in a variety of offices, she noted that these offices provided different spatial experiences. One office would be adequate; another would not. Reviewing these experiences with her in detail

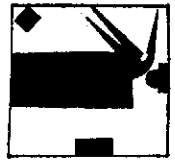
brought out the fact that, like many people, she had a habit of pushing herself away from her desk and leaning back in her chair to stretch her arms, legs, and spine. I observed that the length of the away-from-desk shove was highly uniform, and that if she touched the wall when she leaned back, the office struck her as too small. If she didn't touch the wall, she considered it ample.

Based on interviews of over one hundred American informants, it would appear that there are three hidden zones in American offices:

1. The immediate work area of the desktop and chair.
2. A series of points within arm's reach outside the area mentioned above.
3. Spaces marked as the limit reached when one pushes away from the desk to achieve a little distance from the work without actually getting up.

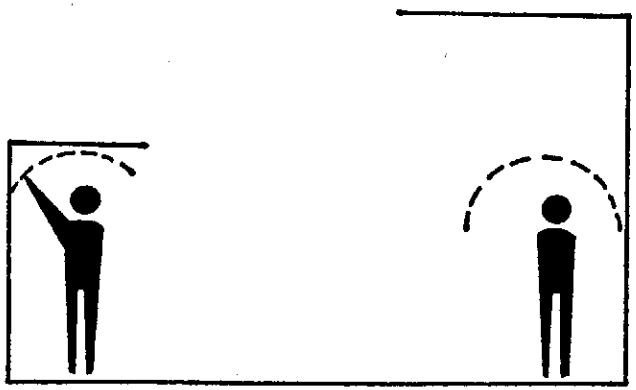
An enclosure that permits only movement within the first area is experienced as cramped. An office the size of the second is considered "small." An office with Zone 3 space is considered adequate and in some cases ample.

Kinesthetic space is an important factor in day-to-day living in the buildings that architects and designers create. Consider for a moment American hotels. I find most hotel rooms too small because I can't move around in them without bumping into things. If Americans are asked to compare two identical rooms, the one that permits the greater variety of free movement will usually be experienced as larger. There is certainly great need for improvement in the layout of our interior spaces, so that people are not always bumping into each other. One woman (noncontact) in my sample, a normally cheerful, outgoing person, who had been thrown into a temper for the umpteenth time by her modern but badly designed kitchen, said:



"I hate being touched or bumped, even by people who are close to me. That's why this kitchen makes me so mad when I'm trying to get dinner and someone is always in my way."

Given the fact that there are great individual and cultural differences in spatial needs (see Chapters X through XII), there are still certain generalizations which can be made about what it is that differentiates one space from another. Briefly, what you can do in it determines how you experience a given space. A room that can be traversed in one or two steps gives an entirely different experience from a room requiring fifteen or twenty steps. A room with a ceiling you can touch is quite different from one with a ceiling eleven feet high. In large outdoor spaces, the sense of spaciousness actually experienced depends on whether or not you can walk around. San Marco Square in Venice is exciting not only because of its size and proportions but because every inch of it can be traversed on foot.



THERMAL SPACE

The information received from the distance receptors (the eyes, ears, and nose) plays such an important part in our daily life that few of us would even think of the skin as a major sense organ. However, without the ability to perceive heat and cold, organisms including man would soon perish. People would freeze in winter and get overheated in summer. Some of the more subtle sensing (and communicating) qualities of the skin are commonly overlooked. These are the qualities which also relate to man's perception of space.

Nerves called the proprioceptors keep man informed of

what is taking place as he works his muscles. Providing the feedback which enables man to move his body smoothly, these nerves occupy a key position in kinesthetic space perception. Another set of nerves, the exterioceptors, located in the skin, convey the sensations of heat, cold, touch, and pain to the central nervous system. One would expect that since two different systems of nerves were employed, kinesthetic space would be qualitatively different from thermal space. This is precisely the case even though the two systems work together and are mutually reinforcing most of the time.

It is only recently that some remarkable thermal characteristics of the skin have been discovered. Apparently, the capacity of the skin both to emit and to detect radiant (infrared) heat is extraordinarily high, and one would assume that this capacity, since it is so highly developed, was important to survival in the past and may still have a function. Man is well equipped both to send and to receive messages as to his emotional state by means of changes in the skin temperature in various parts of the body. Emotional states are also reflected in changes in the blood supply to different parts of the body. Everyone recognizes the blush as a visual sign; but since dark-skinned people also blush, it is apparent that the blush is not just a matter of change in skin coloration. Careful observation of dark-skinned people when they are embarrassed or angry reveals a swelling of the blood vessels in the region of the temples and the forehead. The additional blood, of course, raises the temperature in the flushed area.

New instruments have made possible the study of heat emission, which should eventually lead to research in the thermal details of interpersonal communication, an area previously not accessible to direct observation. The new instruments referred to are infrared detecting devices and cameras (thermographic devices) originally developed for satellites and homing missiles. Thermographic devices are wonderfully adapted to the recording of subvisual phenomena. R. D. Barnes in a recent article in *Science* tells how photographs taken in the dark using the radiant heat of the human body show some remarkable things. Skin color, for example, does not affect the amount of heat emitted; dark skins emit no more and no less heat than light skins. What does have an

effect is the blood supply in a given area of the body. These devices confirm the fact that an inflamed area of the body is actually several degrees hotter than the surrounding area, a condition which most of us can detect by touch. Blockages affecting the circulation of the blood and disease (including cancer of the breast in women) can be diagnosed using thermographic techniques.

Increased heat at the surface of someone else's body is detected in three ways: first, by the thermal detectors in the skin, if two subjects are close enough; second, by intensifying olfactory interaction (perfume or face lotion can be smelled at a greater distance when skin temperature rises); and third, by visual examination.

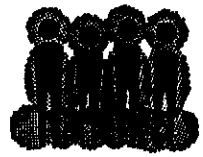
When I was younger, I often observed while dancing that not only were some of my partners hotter or colder than average, but that the temperature of the same girl changed from time to time. It was always at that point, where I found myself establishing a thermal balance and getting interested without really knowing why, that these young ladies would inevitably suggest that it was time to "get some air." Checking on this phenomenon years later, I mentioned thermal changes to several female subjects and learned that they were quite familiar with them. One subject claimed that she could tell the emotional state of her boy friend even at a distance of three to six feet in the dark. She reported that she could detect the point at which either anger or lust was beginning to take over. Another subject used to rely on temperature changes in the chest of her dance partners and would take corrective action before things "went too far."

One might be tempted to scoff at observations such as these if it weren't for a report by one of our scientific investigators of sex. In a paper presented to the American Anthropological Association in 1961, W. M. Masters showed with the use of color slides that a rise in temperature of the skin of the abdomen is one of the very early indications of sexual excitement. Taken by themselves, the reddening of the face in anger, the blush of embarrassment, the red spot between the eyes indicative of the "slow burn," the sweating palms and the "cold sweat" of fear, and the flush of passion are little more than curiosities. Combined with what we know of be-

[illegible] in lower life forms, they can be seen as significant [illegible]nts of displays—behavioral fossils, you might say—which originally served the purpose of letting the other person know what was going on.

This interpretation seems even more plausible when we take into account the possibility suggested by Hinde and Tinbergen that display in birds is probably under the same nervous control as the use of the feathers in cooling and warming. The mechanism apparently functions somewhat as follows: A male bird in the presence of another male gets angry, which sets in motion an elaborate complex of messages (endocrine and nervous) to different parts of the body, preparing the bird for combat. One of the many ensuing changes is an increase in temperature, which in turn results in the puffing out of the feathers as though it were a hot summer day. The mechanism is very similar to the thermostat on the early cars that opened and closed the louvers on the radiator when the motor was hot or cold.

Temperature has a great deal to do with how a person experiences crowding. A chain reaction of sorts is set in motion when there is not enough space to dissipate the heat of a crowd and the heat begins to build up. In order to maintain the same degree of comfort and lack of involvement, a hot crowd requires more room than a cool one. I had occasion to observe this one time when my family and I were traveling to Europe by air. There had been a series of delays, and we were forced to stand in a long queue. Finally we were moved from the air-conditioned terminal to another line outside in summer heat. Even though the passengers were no closer together, the crowding was much more noticeable. The significant factor that changed was the heat. When thermal spheres overlap and people can also smell each other, they are not only much more involved but, if the Bruce effect mentioned in Chapter III has meaning for humans, they may even be under the chemical influence of each other's emotions. Several of my subjects voiced the sentiments of many non-contact peoples (the ones who avoid touching strangers) when they said that they hated to sit in upholstered



chairs immediately after they had been vacated by someone else. On submarines, a frequent complaint of the crew is about "hot bunking," the practice of sharing bunks, so that as soon as one watch "crawls out of the sack" the relieved watch takes their place. We do not know why one's own heat is not objectionable and a stranger's is. Possibly this is due to our great sensitivity to small temperature differences. People seem to respond negatively to a heat pattern that is not familiar.

Interpretation of the awareness (or lack of it) of the many messages that we get from our thermal receptors poses certain problems for the scientist. The process is more complex than is apparent at first. The secretions of the thyroid, for example, alter cold sensitivity; hypothyroidism causes subjects to feel cold, while hyperthyroidism produces the opposite effect. Sex, age, and the individual chemistry are involved. Neurologically, heat regulation lies deep in the brain and is controlled by the hypothalmus. But culture, too, obviously affects attitudes. The fact that humans can exert little or no conscious control over their entire heat system may explain why so little research has been done on the matter. As Freud and his followers observed, our own culture tends to stress that which can be controlled and to deny that which cannot. Body heat is highly personal, and is linked in our minds with intimacy as well as with childhood experiences.

The English language abounds with such expressions as "hot under the collar," "a cold stare," "a heated argument," "he warmed up to me." My experience in conducting proxemic research leads me to believe that these expressions are more than mere figures of speech. Apparently, man's recognition of the changes in body temperature, both in himself and in others, is such a common experience that it has been incorporated into the language.

An additional method of checking on man's response to thermal states in himself and in others is to use one's self as a control. My own increased awareness has taught me that the skin is a much more constant source of information at a distance than I had ever supposed. For example, once when I was attending a dinner party, the guest of honor was holding forth and everyone's attention was focused on him. While

listening attentively, I realized that something had caused me to withdraw my hand from the table with reflex speed. I had not been touched, yet an unknown stimulus had produced an involuntary jerk of my hand which startled me. Since the source of the stimulus was unknown, I placed my hand back where it had been before. I then noted the hand of the guest next to me resting on the tablecloth. I remembered vaguely detecting the peripheral visual image of her putting her hand on the table while she listened. My fist had been within heat range, which turned out to be a full two and a half inches! In other instances, I have been fully aware of the heat of people's faces at eleven to eighteen inches as they leaned over me while looking at something in a picture or a book.

The reader can easily test his own sensitivity. The lips and the back of the hand generate a good deal of heat. Placing the back of the hand in front of the face and slowly moving it up and down at different distances enables one to establish a point at which heat is readily detected.

The blind are a good source of data on sensitivity to radiated heat. However, they are unaware of their own sensitivity in the technical sense and do not talk about it until alerted to look for thermal sensations. This was discovered during interviews conducted by a psychiatric colleague (Dr. Warren Brodey) and myself. We were investigating the use of the senses by blind subjects. During the interviews the subjects had mentioned the currents of air around windows and how important windows are to the blind for non-visual navigation, enabling them to locate themselves in a room and also to maintain contact with the outdoors. Hence, we had reason to believe that it was more than a heightened sense of hearing that enabled this group to navigate so successfully. At subsequent sessions with this group, repeated instances were reported in which the radiant heat of objects was not only detected but had been used as an aid in navigation. A brick wall on the north side of a given street was identified as a landmark to the blind because it radiated heat over the total width of the sidewalk.

TACTILE SPACE

Touch and visual spatial experiences are so interwoven that the two cannot be separated. Think for a moment how young children and infants reach, grasp, fondle, and mouth everything, and how many years are required to train children to subordinate the world of touch to the visual world. Commenting on space perception, the artist Braque distinguished between visual and tactile space thus: "tactile" space separates the viewer from objects while "visual" space separates objects from each other. Emphasizing the difference between these two types of space and their relations to the *experience* of space, he said that "scientific" perspective is nothing but an eye-fooling trick—a bad trick—which makes it impossible for the artist to convey the full experience of space.

James Gibson, the psychologist, also relates vision to touch. He states that if we conceive of the two as channels of information in which the subject is actively exploring (scanning) with *both* senses, the flow of sense impressions is reinforced. Gibson distinguishes between active touch (tactile scanning) and passive touch (being touched). He reports that active touch enabled subjects to reproduce abstract objects that were screened from view with 95 per cent accuracy. Only 49 per cent accuracy was possible with passive touch.

Michael Balint, writing in the *International Journal of Psychoanalysis*, describes two different perceptual worlds, one *sight oriented*, the other *touch oriented*. Balint sees the touch oriented as both more immediate and more friendly than the sight oriented world in which *space* is friendly but is filled with dangerous and unpredictable objects (people).

In spite of all that is known about the skin as an information-gathering device, designers and engineers have failed to grasp the deep significance of touch, particularly active touch. They have not understood how important it is to keep the person related to the world in which he lives. Consider Detroit's broad-base behemoths that clog our roads. Their great size, davenport seats, soft springs, and insulation make each ride an act of sensory deprivation. American automobiles

are designed to give as little feeling of the road as possible. Much of the joy of riding in sports cars or even a good European sedan is the sense of being in contact with the vehicle as well as with the road. One of the attractions of sailing, in the view of many enthusiasts, is the interplay of visual, kinesthetic, and tactile experiences. A friend who sails tells me that unless he has the tiller in his hand, he has very little feeling of what is happening to the boat. There is no doubt that sailing provides its many devotees with a renewed sense of being in contact with something, a feeling we are denied by our increasingly insulated, automated life.

In times of disaster, the need to avoid physical contact can be crucial. I am not speaking about those incidents of critical overcrowding that induce disaster, like the slave ships with 1.1 to 8.0 square feet per person, but supposedly "normal" situations in subways, elevators, air-raid shelters, hospitals, and prisons. Most of the data used to establish criteria for crowding are inappropriate because they are too extreme. Lacking definitive measures, those who study crowding repeatedly fall back on incidents in which the crowding has been so extreme as to result in insanity or death. As more and more is learned about both men and animals, it becomes clearer that the skin itself is a very unsatisfactory boundary or measuring point for crowding. Like the moving molecules that make up all matter, living things *move* and therefore require more or less fixed amounts of space. Absolute zero, the bottom of the scale, is reached when people are so compressed that movement is no longer possible. Above this point, the containers in which man finds himself either allow him to move about freely or else cause him to jostle, push, and shove. How he responds to this jostling, and hence to the enclosed space, depends on how he feels about being touched by strangers.

Two groups with which I have had some experience—the Japanese and the Arabs—have much higher tolerance for crowding in public spaces and in conveyances than do Americans and northern Europeans. However, Arabs and Japanese are apparently more concerned about their own requirements for the spaces they live in than are Americans. The Japanese, in particular, devote much time and attention to the proper or-

ganization of their living space for perception by all their senses.

Texture, about which I have said very little, is appraised and appreciated almost entirely by touch, even when it is visually presented. With few exceptions (to be mentioned later) it is the memory of tactile experiences that enables us to appreciate texture. So far, only a few designers have paid much attention to the importance of texture, and its use in architecture is largely haphazard and informal. In other words, textures on and in buildings are seldom used consciously and with psychological or social awareness.

The Japanese, as the objects they produce indicate so clearly, are much more conscious of the significance of texture. A bowl that is smooth and pleasing to touch communicates not only that the artisan cared about the bowl and the person who was going to use it but about himself as well. The rubbed wood finishes produced by medieval craftsmen also communicated the importance they attached to touch. Touch is the most personally experienced of all sensations. For many people, life's most intimate moments are associated with the changing textures of the skin. The hardened, armorlike resistance to the unwanted touch, or the exciting, ever-changing textures of the skin during love-making, and the velvet quality of satisfaction afterward are messages of one body to another that have universal meanings.

Man's relationship to his environment is a function of his sensory apparatus plus how this apparatus is conditioned to respond. Today, one's unconscious picture of one's self—the life one leads, the minute-to-minute process of existence—is constructed from the bits and pieces of sensory feedback in a largely manufactured environment. A review of the immediate receptors reveals first that Americans who live urban and suburban lives have less and less opportunity for active experiences of either their bodies or the spaces they occupy. Our urban spaces provide little excitement or visual variation and virtually no opportunity to build a kinesthetic repertoire of spatial experiences. It would appear that many people are kinesthetically deprived and even cramped. In addition, the automobile is carrying the process of alienation from both the body and the environment one step further. One has the

feeling that the automobile is at war with the city and possibly with mankind itself. Two additional sensory capacities, the great sensitivity of the skin to changes in heat and texture, not only act to notify the individual of emotional changes in others but feed back to him information of a particularly personal nature from his environment.

Man's sense of space is closely related to his sense of self, which is in an intimate transaction with his environment. Man can be viewed as having visual, kinesthetic, tactile, and thermal aspects of his self which may be either inhibited or encouraged to develop by his environment. Chapter VI considers man's visual world and how he builds it.