Space and the Strategy of Life*

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ABSTRACT. Space has value to life as a continuum which contains resources and provides experiences. Effective utilization of resources has culminated in the evolution of both aggressive defense of area and the formation of groups which share the same range. To the extent that an individual is alone when he experiences some aspect of his environment, he incorporates that item into his personality. The presence of others within his extended ego boundary may generate anxiety and produce defensive antagonism. This process of developing an identity with surroundings initiates the formation of a second kind of space within which we spend our lives. The experience of things becomes transformed into concepts about them until evolution produces a conceptual space in which values are related to relationships between abstract ideas rather than to ways of behaving in relation to physical situations. The responsible choice among ideas forming one's conceptual space replaces the search for resources in physical space. Commitment to abstract values which guide action replaces aggressive defense of physical objects incorporated into one's ego. Compassion --the understanding support of others with differing values--replaces submission to aggressive action. Evolutionary progression tends to increase the time and energy devoted to conceptual space. Herein lies a partial solution to the population dilemma. Increase in numbers must cease within the next century. Nevertheless, evolutionary progression may continue through enlargement of conceptual space. Promoting enlargement of conceptual space requires increasing diversity of physical and ideational resources, kinds of living units, and assemblies they form, while increasing the number and effectiveness of

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links between these diverse elements and assemblies. Promotion in this sense will replace conservation as we--with compassion--guide the destiny of Earth toward creative exploitation of conceptual space through responsible commitments.

INTRODUCTION

Many traditions mingle in my past. Each in some way contributes to my concern with space. One of these traditions involves the Scottish people.* Their history embraces the development of the clan system as an eminently successful means of adjusting to life in a trying terrain. This very success led to dismal failures as many strictures, from the statutes of Iona in 1600 to the Battle of Culloden in 1746, dissolved clan authority. I come from a long line of Calhouns often characterized by failure to maintain territorial prerogatives. Just before 1600, the Colquhoun clan was resoundingly massacred in Glen Fruin above Loch Lomond by the immediate ancestors of Rob Roy MacGregor. This local fracas was part and parcel of a more general tension accompanying the incipient population explosion which resulted in part from a decline in the authority of clan chiefs to control marriage. Even at this early date the impinging of population on available space stimulated 35,000 Scots to settle in northern Ireland during the first two decades of the 1600s. By a century later, the prolific Scots in northern Ireland were again in a population and space bind. The Calhouns were on the march again. Some few years of wandering later, a large part of the American branch of the clan, some 150 strong, found themselves crossing Long Cane Creek in South Carolina one fine day in 1760. In a typical Calhoun error in tactics, the men stacked their guns and went down to help extract a wagon mired as it was crossing the creek. While so engaged, a band of Cherokees massacred a third of their number. Of the survivors the more activist half remained and established the settlement of Abbeville. Out of this group stemmed "John C.", whose place in history depends upon your point of view. The other half of the survivors retreated back up into North Carolina to the protection of the earlier Scottish settlement of Waxhaw. I come from this cowardly branch of the Calhouns. They tended to produce teachers and preachers, to retreat into the world of ideas.

Whether this family history has any bearing on my specific scientific concern with the subject of space, I do not know. However, it exemplifies the central theme of my presentation, that there are two kinds of space, one physical and one conceptual. If we are to grapple successfully with the myriad crises and tensions accompanying the developing rapid increase in human numbers, both physical and conceptual space need to be considered.

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* Irrespective of the relationship of Scottish history to the origin of my research interests, I have found its perusal stimulating in evolving insights about the influence of space on man [17,18,28,29,34].

My own strategy for avoiding the pressures of the present has been to escape by seeking only to understand the life and times of lower mammals [6,7,8]. During each such reclusion I keep stumbling on to principles which seem to have some bearing on the human situation also. And yet, my very immersion with these problems makes it difficult for me to recognize whether I have been just wandering in a sterile wilderness or am in fact approaching a frontier of science, a zone of tension and change between traditional systems of thought. You will clearly recognize that much of what I will say may be classified as poetry rather than normal science.* I say this without apology for it is my firm conviction that there is no science which did not have its earlier expression as an art form.

Tonight I am here as a replacement for a very kindred spirit whom I deeply respect, Professor Konrad Lorenz. His life and work exemplify the tension at the interface between art and science.** He flows easily across this boundary, now playing the role of artist and then again the role of scientist. Neither he nor I are either competent or temperamentally inclined to present an adequate summary of the great diversity of effort and thought which many investigators are now directing toward developing an understanding of the importance of space to the life of animals and man. The present symposium on this topic reflects the broad scope of this emerging field of science.

Let us now turn to some of the studies now underway at my laboratory. They will serve as a point of departure to related issues more particularly characterizing the human scene.

EXPERIMENTAL UNIVERSES

An experimental universe is a bounded physical space consisting of one or more similarly constructed cells (Figure 1). Each cell provides opportunity for the expression of many of the behaviors characteristic of the species for which the universe is intended as a place of habitation. The example shown here is of a four-cell universe designed for house mice. The floor is merely a large tray, 51 x 51 inches, covered to a depth of three inches with ground corn cobs. Partitions, slightly higher than the surface of the ground corn cobs, divide the floor space into four equal areas, each covering 640 square inches. Mice utilize these partitions as boundaries of territories. A chemical ring stand with its base covered by the

* Kuhn makes a particularly strong argument for the necessity of a more artistic form of expressing the formulations of the scientific revolutions which later permit a new field of normal science to emerge [26, p.172].

** Konrad Lorenz discusses the juncture of art and science in the development of new value systems, new ways of viewing life and functioning in it [27, p.286-299].

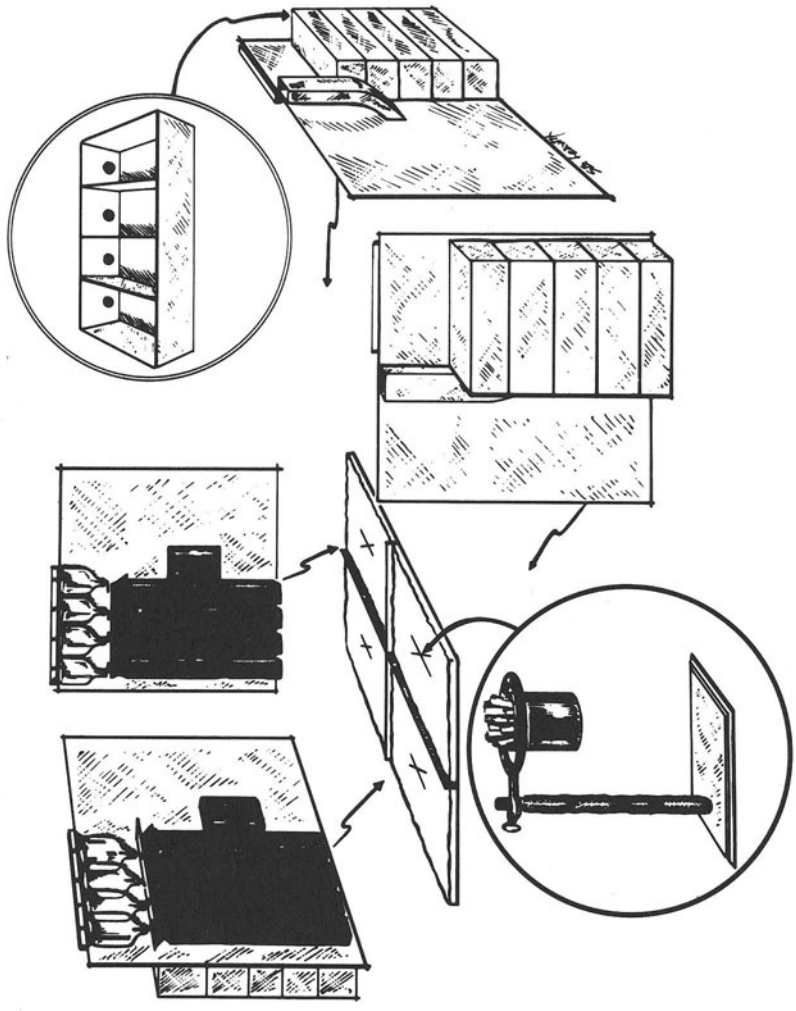


Figure 1: A four-cell universe for mice

ground corn cobs is placed in the center of the floor of each cell. Wire screen wrapped about the rod enables the mice to climb up and procure nesting material from the can suspended within the ring. In point of fact this structure becomes the focus of a number of kinds of activities. For example, during the hours of heightened activity it often serves as a temporary haven for subordinate mice. The four wall sections, shown displaced in the figure, are bolted together about the base to form the closed universe. Adjacent to the floor space of each cell, four vertical wire screen tunnels give the mice access to a battery of sixteen nesting compartments, four at each of four levels in each cell.

In each battery each of the four levels contains four nest compartments. This arrangement does make an efficient use of space. However, the prime function of this arrangement is to introduce the economic factor. The higher up a mouse lives in this apartment complex, the lower is its income because it must expend more energy during each round trip from its home to obtain such resources as food and water. Food is provided in a hopper in each cell located on the wall to the right of the tunnels. Obtaining food requires that the mouse run across the outer surfaces of the tunnels to the hopper and hang on it while it gnaws at the contained pellets of food. An outside accessory hopper enables the food surface to be covered with food at all times. Four 2500 cc bottles suspended above a platform above the tunnels provide an ample source of water.

This spatial arrangement will permit in excess of 250 mice per cell, in this case more than 1000 mice per four-cell universe before "standing room only" and lack of opportunity to gain access to resources places an upper limit on population level. Our present program is particularly focused on trying to understand the conditions which permit or prevent the population from arriving at the "standing room only" terminal stage.

THE BEHAVIORAL SINK

Among the studies now underway is one in which we are investigating the effect of group size on social withdrawal. Each group consists only of males introduced at weaning. The number of mice in the four groups are four, eight, sixteen, and thirty-two. Each group inhabits a four-cell universe. So far we do not know what the optimum size group is for this universe, although we suspect that it is more than eight, but less than sixteen. Above the optimum size group a strange pattern of eating is developing (Figure 2).

Each bar graph represents the percentage of the food consumed from the food hopper located at approximately the position shown in the diagrammatic cross section of the universe. It will be noted that as the group size gets larger, the deviation from equal usage of the four hoppers becomes more accentuated. From past experience

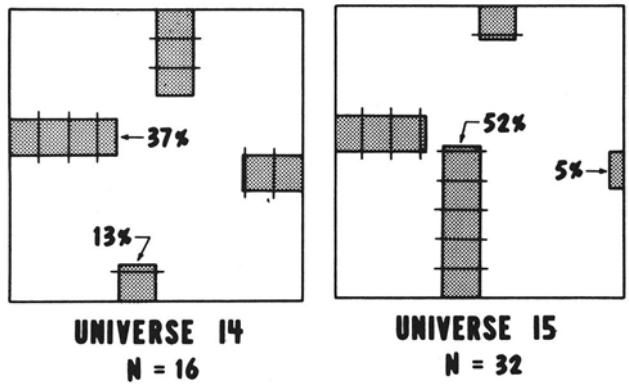


FIGURE 2 - BEHAVIORAL SINK DEVELOPMENT IN MICE

Diagrammatic representation of food consumption, 13 Sept.-12 Nov., 1968. Bar graphs indicate percentage of food consumed from each of the four food hoppers in each universe.

with other similar type studies of rodents, I can predict with fair assurance that this trend will continue to become more accentuated, particularly in the larger group. The end state will be one in which over 90% of food consumption takes place from one hopper and essentially none from at least two of the others. This will mean that most of the mice eat only at this one hopper and all of them eat mostly there.

This end state represents the development of what I term the "behavioral sink". However, the concept of the behavioral sink encompasses both the development of the end state and the consequences of its continuance upon the contained individuals. For it to develop, the physical environment must contain a few localized response-permitting situations which require that any individual spend an appreciable span of time at one of them in completing the appropriate response. Gnawing at food through the mesh of a food hopper represents such a situation. When few animals are present, the usual circumstances will be that each individual will terminate most episodes of eating without another mouse being present on the hopper. However, as the group increases in size, the chances increase that while one individual is still eating another will join him at the same hopper. After a number of such coincidences of joint eating in close proximity, each individual comes to associate the presence of another with the reward of eating. This association becomes so strong in time that

the eating situation is redefined by the mice as requiring the presence of an associate. Most mice will return to that particular hopper and at those particular times of day previously characterized by the highest probability of finding other mice present. At the terminal stage of the process the aggregates at a particular hopper may be so large that most individuals experience some difficulty in completing any particular episode of eating. This derived heightened need for proximity to others becomes pathological. It becomes pathological because it increases the number of social contacts far beyond that which the overall density of the universe would otherwise evoke. I shall return shortly to this question of the relevance of the number of contacts per unit time.

Although this kind of environment was designed by intent to permit the development of the behavioral sink, the very confirmation of its anticipated development tells us how not to design an environment. It points to the detrimental consequences of a static environment, particularly ones where any of the kinds of response situations are highly restricted in number and place. On a theoretical basis, increasing uncertainty, enhancing the necessity for searching and demanding continual solution of new problems should prove beneficial as a basic strategy of environmental design. However, the cost, complexity, and magnitude of such studies have so far forced us to resort to crude simulations on paper as an interim strategy for readying ourselves for such critical studies in the future.

THE BREAKDOWN OF SOCIAL CONTROL OF POPULATION GROWTH

In 1963 Kessler, then of the Rockefeller Institute, began one of the most important experimental studies of population of recent years [24]. His universes were of approximately the same size as the four-cell one which I am now using. However, in order to study selection under crowded conditions, he initiated each of his two universes with 16 pairs of mice, four pairs each of four inbred strains. At the termination of his studies, one universe contained 800 and the other 1000 individuals. When I saw this terminal phase of his study, I concluded that this unusual attainment of very high density must have in some way been dependent upon the large number of initial colonizers. How this insight led to our current large-scale study requires a brief historical background. Before he initiated his study, Kessler asked my advice about an appropriate size for the habitat. I had then just completed an analysis of the minimum spatial requirements to be utilized in experimental studies of group behavior and population dynamics in a range of animals from mice to monkeys. For a colony of mice, this minimum lay between 80 and 100 square feet with considerable additional vertical structuring of retreat or nesting spaces. Due to the strictures of available laboratory space, Kessler was forced to reduce his experimental pens to one-fourth that which I had thought necessary. Moreover, his background as a physician left him unencumbered by presumed ecological truisms, whereas my thinking

had stemmed from an ecological model which says that ecologists "know" how natural populations are initiated. That is, the population is assumed to start from a very few survivors following some catastrophe. Therefore, I was thinking in terms of introducing only one or two pairs of animals into the "minimum" space.

Since Kessler wished to study the interrelationship between crowding and natural selection utilizing coat-color gene markers, his basic stock consisted of four inbred strains of house mice. To reduce initial gene drift, he took recourse to two strategies. First he established a hybrid stock of hybrids, H_3, in which $H_3 = H_1 \times H_2$, and $H_1 = A \times B$, and $H_2 = C \times D$, in which A, B, C, and D were the inbred stocks. Second, he started his populations off with 16 pairs. Thus he began with 32 to 64 times the density (one-fourth the space and eight to sixteen times the number of colonizers) that my ecological evaluation deemed appropriate. The population eventually reached "standing room only", less than three square inches per mouse. How could this be reconciled with my earlier studies of population growth and social behavior in experimental environments? In these earlier experiments, the presumed "minimum" desirable space was exceeded and, confirming the results of most other workers, an upper level of population was reached far below that attained by Kessler's study.

In order to evolve a more precise hypothesis, I tried to visualize two pairs and 64 pairs of mice in separate "minimum" area environments, as follows: In the lower-colonizing-density situation, each male would often roam about without encountering his associate male companion. This solitary roaming permitted incorporation of many objects into each individual's personal space. All of these objects with which each mouse gained identity became part of its extended self. Each individual's body, by such measure, became larger. Two individuals could thus collide even though their physical bodies were some distance apart by one of them merely occupying or passing through a space that the other had come to identify as part of himself. Therefore, when two individuals did approach each other, such a collision at a distance would generate anxiety and precipitate intense fighting, culminating in relatively large territories for each male. This intense territorial strife would reflect back on the female associates who would then experience initial difficulty in conceiving and rearing litters. In contrast, in the case where there were 16 males in the same amount of space, any colonizing male would typically encounter another male during his periods of exploration. Therefore, the number and spatial extent of objects incorporated within any individual's extended identity would be much reduced. As a consequence, the frequency and intensity of fighting would be markedly reduced and territories rarely established. With little stress from male aggression impinging upon them, females would be subject to very little inhibition of conception or maternal care. As a consequence, populations initiated with a high density of colonizers should reach very high terminal densities approaching "standing room only."

This line of reasoning led to a rather extreme hypothesis: "The greater the density of initial colonizers, the greater the terminal density". To explore this hypothesis, Gerald G. Wheeler and I developed a series of experiments in which both the amount of space and the number of colonizers were varied. Units of space (the "cells" shown in Figure 1) were varied in an ascending series of one, two, four, eight and sixteen cells to form closed physical "universes" of increasing size. Five universes of each size were to be colonized with one, two, four, eight and sixteen pairs of mice, respectively. All 25 universes were designed and constructed; however, a shortage of personnel dictated an initial constriction of effort. We decided to restrict our first effort to one universe of each size, each initiated with four pairs of mice (the midpoint number of colonizers of our original design).

Preceding the initiation of this study, Charles L. Bishop of our staff ran a pilot study of a one-cell universe with four pairs of colonizers. This population, in a space approximately one-fourth of that Kessler used, reached an upper level of 250 adult mice, exactly one-fourth of the "standing room only" level reached in Kessler's study. With this confirmation in hand, and considering the hypothesis stated above, we proceeded to a second level hypothesis relating to the five-universe study we then initiated: "The larger the physical space when there are several colonizing pairs, the smaller will be the absolute size of the population when the maximum number is attained." From the one-cell to the 16-cell universe, the predicted terminal population would be respectively, 250, 230, 205, 168, and 110; and in relative density (i.e., number of mice per cell) the series predicted would be 250, 115, 51, 21, 7. This hypothesis was presented in my AAAS Frontiers of Science Lecture in December 1968 at a time when the populations were in their earliest phases of development and so far confirmed the hypothesis.

This confirmation lay only in the initial history of these populations. Within the first two months after introduction, two of the males in the largest universe (16 cells) succumbed from the stress accompanying their intense fighting. Likewise, one soon died in the second largest universe (eight cells), and after a longer time, one also died in the middle-sized universe (four cells). In contrast, there were no deaths of colonizers for many months in the two smallest universes. In them fighting among colonizers was relatively subdued and was accompanied by an even more interesting phenomenon--self-grooming became transformed into mutual grooming. That is, each individual's identity became fused with others. Such mutual grooming among colonizers was never observed in the two larger universes. Instead, the more classical picture of territoriality and hierarchies developed with the overflow of stressful situations affecting females to the extent of reducing conception and interfering with proper maternal behavior. In contrast, this feedback loop, which functions to inhibit population growth, hardly functioned during the establish-

ing phase of the two smaller universes. For example, the first surviving litters were born 25 days after colonization in the two smaller universes, but not until 50 days in the two larger ones.

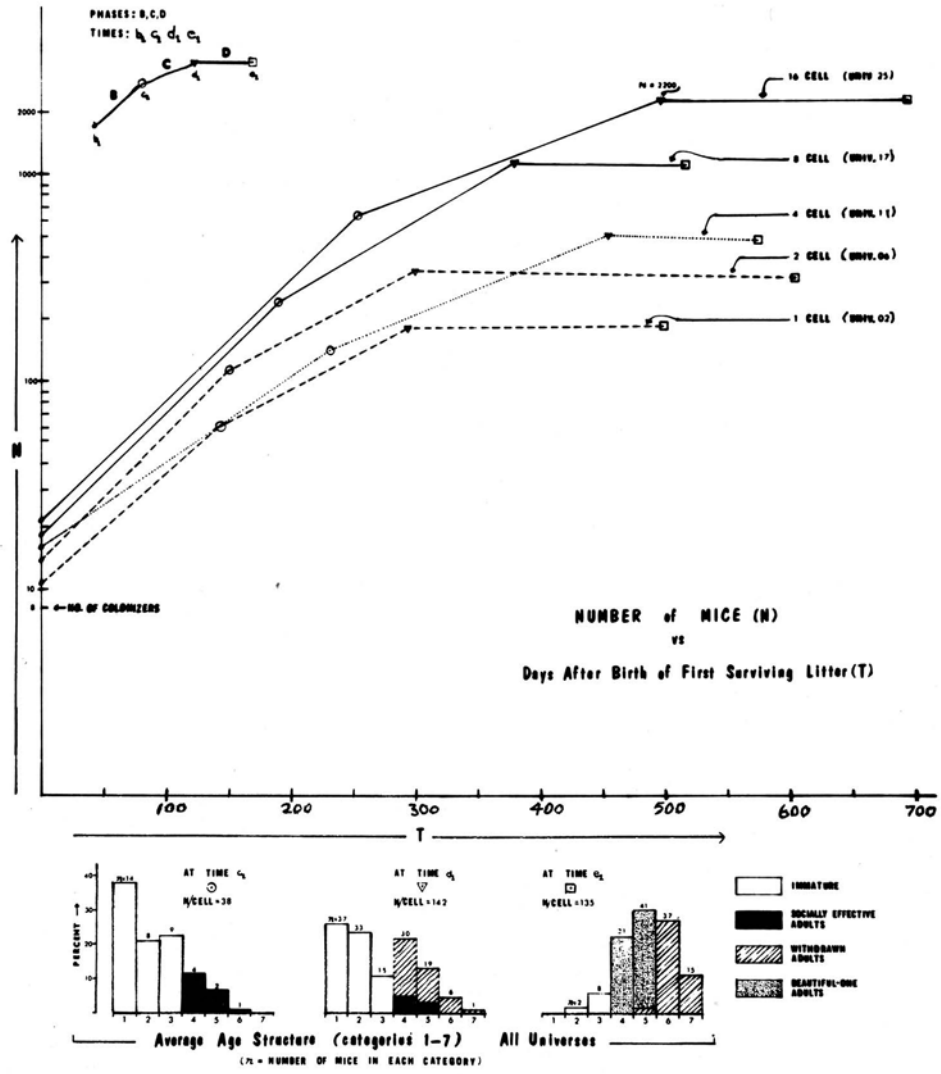


FIG. 3 POPULATION GROWTH AND AGE STRUCTURE OF MICE

The remaining histories of these colonies (Figure 3) only partially substantiated the original hypothesis. It is obvious from this figure of population growth that the larger universes culminated

in larger absolute populations than the smaller ones. At the upper limit of population growth (at time d_1 on the curves) the number of mice per cell from the smallest to the largest universe was respectively, 180, 175, 130, 142, 138. The middle-sized universe, the one with four cells, had a history of unusual social disturbance which seemed to stem from an exceedingly pathological aggressiveness of the one territorial male among the colonizers. Both of the two initial phases of population growth in this four-cell universe exhibit a marked reduction in the rate of increase in contrast to that holding in the other four. Therefore, if we ignore this universe and focus only on the other four, it may be seen that the final density (180 and 175) of the two smaller universes was 25% greater than that of the final density (142 and 138) for the two larger ones. This is the extent of the confirmation of the original hypothesis. However, similarities in the histories of all universes have produced insights that are of even greater significance.

To appreciate these new insights, mention must be made of changes in the physical environment. In the original designing of the universes, Wheeler came up with the concept of "physiological" physical space as opposed to "social" physical space. "Physiological" space is that where ingestion of food and water takes place, and where the animals retreat to rest and rear their young. "Social" space is that where status interactions take place. In the original design, a water source inserted into the back of each of the 16 nesting compartments in each cell and a food hopper forming the false roof of each compartment confined these more basic survival behaviors of ingestion, sleep, and reproduction to these retreat spaces. All external space was left for more involved social interactions. However, since mice tend to urinate and defecate near where they eat and drink, this design led to such a fouling of nests and high humidity in them that the overhead food became extremely moistened and caked, making it less accessible and desired by the mice. For this reason, the food and water sources had to be shifted out from the retreat compartments to the positions shown in Figure 1. This still left the floor as more truly "social" space. We believe that this change in physical environmental structure increased the amount of stress experienced and was instrumental in producing a reduction of maximum density in the one-celled universe--180 in contrast to 250 obtained in the pilot study. This change in environment was made in December 1968, five months after colonization and during the writing of the original draft of this paper. With this background we may now examine the longer history of these populations.

All populations passed through four discrete phases:

Phase A: The establishing phase extending to the time of birth of the first surviving litter.

Phase B: Period of rapid population growth during which on the average the population doubles every 56 days.

Phase C: Period of reduced rate of population growth during which on the average the population doubles every 105 days.

Phase D: Period of stability, or slight decline (less than five percent) of population numbers.

A schematic representation of the last three phases is shown in the upper left corner of Figure 3. Times c_1, d_1, and e_1 mark the ends of Phases B, C, and D, respectively. In all cases, the end of Phase D at e_1 might have extended beyond that shown. The one, two, four and eight-celled universes were terminated at the e_1 times shown. The 16-celled universe is being continued to determine if later periods of either rapid decrease or increase may occur. For each universe age cohorts were established for those born each ten days after colonization and the number surviving each ten days thereafter calculated from the observed dates of birth and death (or survival to termination of the colony). From these source data the growth curves and age structures of the population at the critical times c_1, d_1, and e_1 were calculated. The seven age categories represent meaningful biological-social periods of life:

Category Number	Category (cohort)	Span in Days From Birth
1	Preweaning	1 to 30
2	Juvenile	31 to 70
3	Subadult	71 to 130
4	Establishing Adult	131 to 210
5	Adult	211 to 320
6	Declining	321 to 450
7	Senescent	451 and over

The three age structure histograms in the lower part of Figure 3 represent averages of those for the five universes at the times indicated.

Over most of Phase B (rapid population growth), the social structure in each universe remained dominated by one or two colonizing males, while successful production of litters was by both colonizing females and subadults. These latter do contribute to population increase provided the ambient social structure is relatively stable with regard to male territories. Practically all litters born during this phase survived. Toward the end of this phase, males began entering the Establishing Adult age category. This indicates that they have reached an age when they can effectively contend with each other and with the older colonizing males for territories and dominance status. This Phase B terminated at time c_1 with an average of 38 mice per cell. Of these, six to seven were in the Establishing Adult and Adult age categories. However, the average territory covered approximately

one and one-half cells, which means each territory on the average included 10 - 11 mice in socially active age categories. For reasons not now well understood, the sex ratio in these five universes held quite constant at 40 males to 60 females. Thus, the basic social unit consists of one territorial male, three contesting but subordinate males and six effectively reproducing females. At the end of Phase B, all universes were filled with such basic social units, which on the average inhabited one and one-half cells. At time c_1, the three younger age categories had insufficiently matured to offer any serious competition to these older, socially established mice whose relative numbers are indicated by heavy shading on the age structure graph for time c_1.

During the Phase C period of inhibited population growth, these younger mice born during Phase B successively shifted into the age categories of Establishing Adult and Adult. As they moved into these later ages, they began to contest with the territorial males since there was essentially no vacant space to occupy as a territory. A few were successful, but most, after initial striving, began to withdraw both physically and psychologically. These remarks apply particularly to males. Early in Phase C, when the territories of males still included the nest compartments, these withdrawn rejected males were forced out of the nest compartments to places of rest at the periphery of the territories--out in the center of the floor space or on the water or food platforms. Here they would cower except for minimal movement necessary to obtain food and water. Some continued through most of their lives as Solitary Withdrawns. However, most of the withdrawn males assembled in large aggregates and so have been termed Pooled Withdrawns. During most of Phase C, these withdrawn males were characterized by masses of recent wounds. In only a few instances were these wounds inflicted by territorial males. Periodically, each withdrawn male would burst into a brief flurry of violence in which he would attack one of his associated withdrawn males. The one being attacked would rarely flee, but instead crouched and allowed himself to be bitten. As Phase C proceeded, the extent of territories diminished to an area within a radius of less than 12 inches from the base of the ring stands. As this reduction of male territories took place, the older adult reproducing females became excessively aggressive toward immature mice within the nest compartments and toward any adult of either sex being about the bases of the tunnels leading up into the nest compartments. The age structure graph for time d_1 at the end of Phase C is particularly instructive. By this time, there were at most no more than 10 mice in each cell in the Establishing Adult and Adult age categories (Nos. 4 and 5) who retained even a modicum of normal behavior. They are shown as heavy shading. The hatched portions of the bars for the four older age categories represent the withdrawn mice, 32% of the 142 mice in the average cell. These mice are no longer "mice" in the social sense of contributing to the survival of the species. By this time they have lost to a large extent even the capacity for the violent

type of aggression and the only sexual behavior is a rare episode of over-intense copulation, apparently not involving intromission. Sixty percent of the population, then standing at 14 times the optimum, consisted of those in the three immature age categories, whose fate became apparent only after Phase D began.

Successful rearing of young terminated early in Phase D. The frequency of conception also became markedly reduced, being largely confined to females born early in Phase C. Those mice which had withdrawn during Phase C remained as inactive nonparticipants--but even more so. Even their capacity for violent, nonfunctional aggression disappeared. Those 10 mice per cell who retained some modicum of involvement in social activities during Phase C entered the ranks of the withdrawn mice. No mice replaced them. By midpoint of Phase D there were, for all practical purposes, no territorial males, no contesting males and no reproducing females capable of caring for young; the genetic and learned templates for guiding effective adult behavior had been "washed out" among all who had ever exhibited behavioral competence of a reproductive or aggressive nature.

Such lack of competence also characterized the 53% of the population who had entered age categories 4 and 5, where normally such behaviors would have at least been attempted. We have designated such mice as the "Beautiful Ones." They neither fight nor "sex" nor build nests, nor have they ever exhibited these behaviors during their development to adulthood. They carry no wounds of battle; their pelage remains excellent due to frequent self-grooming. Essentially, they remain as juveniles who age. Like juveniles, they retain the capacity to remain in the nesting compartments during periods of resting. Dr. Julius Axelrod has assayed the enzyme which transforms noradrenalin into adrenalin in this and other categories of mice of Phase D. Unlike the mice who have contested, been rejected, and withdrawn, these "Beautiful Ones" show no evidence of ever being stressed. We can only suspect that some combination of the heightened aggressiveness of adult females during their early development, in conjunction with their experiencing a high rate of contact with other mice, blocked the unfolding of that behavior whose expression is guided by the genetic template. This very early blocking of sexual and aggressive behaviors precludes the possibility of learning elaborating their expression.

When Mayer Spivack of the Department of Community Mental Health, Harvard, viewed these populations during Phase D, he remarked that they were "overliving". By this he meant that all purpose in continued living had been lost once the capacity to engage in those social behaviors requisite to the survival of the species had been suppressed or blocked. If the state of affairs characterizing Phase D persists, the population will eventually completely die off with no reinitiation by the last survivors. This issue is being explored by Halsey Marsden of our staff. I will give a brief overview of his

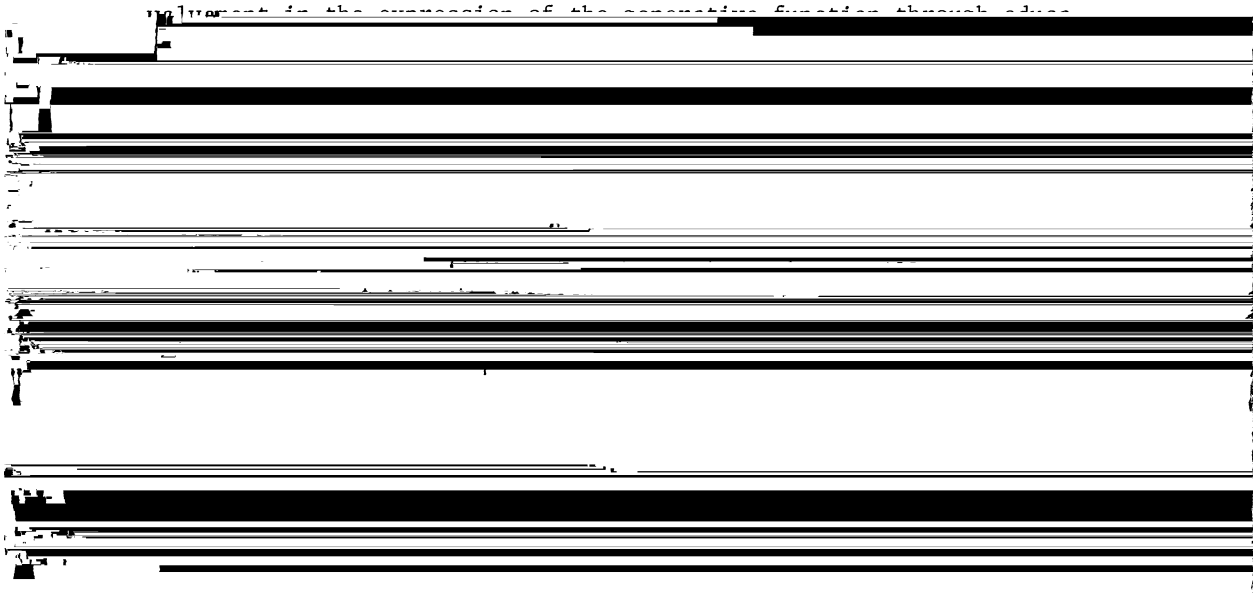
studies: When the two-celled universe was terminated, all were autopsied except for eight males and 16 females (adult mice). At the end of 60 days at this reduced density, territorial behavior had failed to reappear and no pregnancies had resulted. (In contrast, when the original population included 24 Establishing Adult and Adult mice, the total number trebled from 123 to 350 in a similar time period). Gradually, most of the females shifted their residence to the same nest box, as if in an effort to recoup the former nesting compartment density. The females were then placed in an identical universe with eight sexually active males from the stock breeding colony. Even with one sex now competent, only six females conceived and only three of these produced litters. Since these litters were all dropped in the compartment housing 13 of the 16 females, only five pups were reared long enough to indicate that, had this study not been then terminated, they would have been weaned. Furthermore, Marsden has made a detailed study of most categories of males removed from the mid-Phase D period. After intensive observation, 12 mice most representative of each of six categories (territorial, solitary withdrawn, younger pooled withdrawn, older pooled withdrawn, younger beautiful ones, and older beautiful ones) were removed from their environment and each category introduced into its own four-celled universe. Invariably they failed to develop a status ranked social group as might be expected for normal mice. Instead, the typical situation was that of three socially active males and nine who essentially failed to become involved in any social interactions. When competent females from the breeding stock were introduced, extremely few pregnancies resulted; in some cases none. At most, only one or two males in each group had retained the capacity for effective sexual behavior.

We are now continuing the study of Universe 25, the 16-cell universe. There remain two possibilities: First, there will be no further reproduction and the mice will gradually senesce and die, until no more remain. Second, after two or three months more of living in a setting with no significant continuing aggression, the Beautiful Ones may recoup some of their blocked genetic templates to the point that reproductive behavior, unaccompanied by aggression, may be reinstated. The hunch that this possibility may materialize derives from a few observations by Marsden that isolation for two to four months may lead to reinstatement of reproductive behavior. The current absence of social involvement in Universe 25 indicates that for all practical purposes each mouse is isolated from his fellows despite their contiguity.

In searching for the relevance of these studies to the human scene, we must clarify how the present study differs from the natural ecological situation. In a state of nature, available space in acceptable habitats rapidly becomes filled with effective social units --groups of 10 or 12 adult mice. Thereafter, most excess young begin to migrate into less desirable marginal habitats where they are

exposed to predation. In our experimental habitats, the possibility for emigration has been precluded, and predation, except for rare accidental deaths by observer action, has been excluded. Thus, the experimental populations continued to increase to more than 14 times the upper optimum point of 10 adult mice per cell. Furthermore, the static nature of the experimental habitats with localization of food resources fostered development of the behavioral sink phenomenon. Even though the maximum number of mice attained did not preclude mice obtaining enough food, the behavioral sink process culminated in excessive eating in some places while other identical sources were nearly ignored. Among the consequences was that the learned need for proximity to other mice generalized to places of sleeping--to the extent that so many mice would aggregate in nesting compartments that some would suffocate; this, despite the fact that 30% of all nesting compartments at maximum density contained no mice, or only one or two. Such behavioral sinks accentuated the heightened contact rate which culminates in brevity and incompleteness of response and finally blocks expression of behaviors to the point that "Beautiful Ones" are produced. Such behavioral changes must also occur in nature in those rare instances where predation fails to remove the excess population. However, we must conclude that predation and other causes of death normally suffice for natural selection to preserve behavioral repertoires consonant with life within small social groups. The basic conclusion in these studies is that, where density increases beyond the limit of group size and rate of contact compatible with life within a small group, all excess individuals lose, or never develop, the capacity for executing behaviors appropriate to survival of the species.

To transform these insights derived from the study of mice to the human scene requires that we view responsible commitment to values and causes as the sublimated equivalent of fighting in mice. It says that the process of identifying with values and goals beyond the bodily self requires periods of solitude and reflection. In the absence of this opportunity, the individual matures into a hollow, sterile shell incapable of commitments whose pursuit can enlarge the welfare of associates as well as the individual's own self. Paucity of involvement in humans becomes the equivalent of unrestricted population growth in lower mammals. But even the human animal can be caught in this primitive trap. As Erik Erikson so succinctly points out in his lectures on insight and responsibility, where the opportunity for in-



shown by the lower dashed line. That is to say, time will produce an even more marked difference in velocity scores. If one knows only the relative velocity scores of the members of a group, fairly precise predictions can be made about the characteristics of the behavior of each individual. Since the animals shown here are all males, it will be more informative if I present the general picture which has been revealed from our studies of a number of groups of both mice and rats:

For simplicity's sake let us divide any group into an upper, a middle and a lower third according to their velocity scores. The upper third will contain the territorial and other dominant males. They receive relatively few wounds during fights and exhibit normal effective sexual behavior. This normal behavior includes avoiding ingress into abodes where their presence might disturb nursing females. They move with calm assurance through their range. Overall, they exhibit those behaviors most conducive to the reproductive survival of the species. A similar picture holds for the females among the upper velocity ranks. They are the most effective mothers; they construct excellent nests, provide their young with ample opportunity for nursing and move the entire litter from one place to another as

** Eqs. (113) and (126) in J.B. Calhoun, "The Social Use of Space" [9], provide means of calculating expected velocities. Where the number of animals, N, in the universe approximates the optimum number, N_o, for that space and configuration, then the expected velocity, $v^{(exp)}$, may be calculated either as:

$$\frac{N - R + 1}{N}\left[\frac{2\sum_{1}^{N} v^{(obs)}}{N + 1}\right] \qquad \text{(113 derived)}$$

or

$$\frac{N - R + 1}{N}\left[v_{\alpha}^{(obs)}\right] \qquad \text{(126 derived)}$$

where R = Rank of velocity

$v^{(obs)}$ = Observed velocity

$v_{\alpha}^{(obs)}$ = Observed velocity, R = 1

Where the $v^{(obs)}$ approximates the $v^{(exp)}$ from (113 derived) then $N = N_o$ and the social system has obtained equilibrium. From the fact that the $v^{(exp)}$ so calculated for R = 1, and R = 8 are respectively 61.8 and 7.7, it is obvious that either N does not equal N_o or the social system has not yet obtained equilibrium. Other observational data suggest that social equilibrium has not yet been attained. With further withdrawal by lower ranking mice Eq. (126 derived) predicts the dashed line of Figure 4.

this action may decrease the likelihood of interference from invading disturbed adults. As with the males, they exhibit the whole repertoire of behavior most conducive to the reproductive survival of the species.

Individuals in the middle velocity ranks exhibit a strikingly different complex of behaviors. Males rarely win aggressive encounters. Despite this failure, they repeatedly place themselves in positions which elicit attacks from more dominant high velocity males. This arises from a propensity for continual involvement in sexual activities. Despite repeatedly being wounded, such males persist in invading areas dominated by high velocity males which estrous females enter to seek respite from the advances of these lower velocity males. It is this proclivity for involvement in sexual activities, of continual probing into the domains of dominant males, that gives them the appearance of being much more active than their velocity scores reveal. Their sexual behavior exhibits a wide spectrum from near normalcy to extreme deviation. It includes an often heightened intensity of response expressed as maintaining a mount on the female many times the normal duration, and this often without intromission. Furthermore, such males exhibit a wide range of other reproductively ineffective behaviors. They will mount other adult males as well as non-receptive females, and in extreme instances will mount immature individuals of either sex.

The deviance of behavior is equally striking among females of the middle velocity ranks. Though they often become pregnant, their maternal behavior becomes so disrupted as to make the chances of their rearing any young very low. They lose the capacity to build nests or to keep their litters intact at any place. Even when they retain the ability to move their young from the place where a disturbance has occurred, the several members of the litter are deposited at scattered points and eventually deserted. Such females less often reside in areas where they more regularly receive protection from the dominant males from the excessive advances of their lower velocity male associates. As a consequence of the stress experienced, their conception rate becomes reduced, and embryos die before term. Some of the lowest velocity females in this middle group exhibit male sexual behavior. They mount adult males as well as other adult females.

What is most striking about the members of the lowest velocity ranked group is the extreme lack of involvement in social relationships. Part of this lack of involvement may be traced simply to the fact of their rare emergence from those places of retreat utilized mostly by higher velocity individuals only for sleeping. And yet, even when these low velocity individuals do appear, as they must if they are to secure food and water, they neither elicit responses from associates nor actively initiate interactions. They are merely nutritional machines, making no contribution to the reproductive survival of the species. Many of these individuals are so isolated from social

reality that, despite the proximity of associates, these associates just do not seem to exist for them. They do not experience stress from participation in social life. This is reflected by their small adrenals, kidneys and hearts, as well as their exceptionally large deposits of fat.

I have come to the conclusion that this velocity stratification of a group, with all the attendant alterations in behavior, will develop even under the most optimum environmental circumstances. That is to say, it will develop even where all needed physical resources are ample and easily accessible and where no undue crowding exists. At first sight it may seem strange that evolution has allowed such a consequence of group life to persist. We may justifiably wonder why evolution has not maximized normalcy of behavior in terms of a much larger proportion of a group exhibiting those behaviors which contribute to the reproductive survival of the species. It is true that the individuals with reduced velocity and more abnormal behavior do often become active at times and places which expose them to predators. Although this circumstance may contribute to the survival of the more normal segment of the population and thereby increase the chances of their producing progeny successfully, I suspect that this fact has absolutely no bearing on the inevitability of the origin of abnormal behavior, at least abnormal in the sense of not seemingly contributing directly to reproductive survival. This is a very puzzling question. Why should behaviors persist through the history of a species when no individuals which express them leave any significant number of progeny? The obvious explanation is that heredity has little bearing on their origin. I am not proposing that heredity cannot influence the origin of abnormal behavior. Rather, I am proposing that environmental circumstances associated with group living will result in abnormal behavior despite the most advantageous hereditary constitution.

I will shortly return to an explanation of the inevitability of abnormal behavior. Before doing so, we may inquire if there may be some advantage to the development of reduced velocity despite the accompanying abnormal behavior. I would like to share with you the observation that first gave me an insight into this question. In a study of wild rats in a large enclosure, there came a time when the contained population had divided itself into 13 local colonies, each consisting of about 12 adults. One of these was an all male group whose members were quite socially withdrawn; they had developed low velocity status with many of the accompanying abnormal behaviors, including not only considerable homosexual propensities, but also a reduced ability to maintain their burrow in the earth in good repair. And yet they made a discovery which on the human level would be comparable to developing the wheel. In enlarging the tunnel system of a burrow, the usual procedure followed by rats is to scratch loose dirt and then alternately push and kick the loose dirt until it has been deposited on a mound surrounding an entrance. Very rarely, if

the earth is moist, as it often is, rats will exhibit a more efficient method of removing dirt from the burrow. They will pack it into small wads which they will pick up with their teeth and then transport it out in the same fashion that they do small rocks. It is also fairly normal for rats to push and roll out larger rocks which they encounter during their excavations. What these fairly withdrawn, abnormally behaving rats did was to discover how to build an artificial round rock just smaller than the diameter of the tunnels. What they did involved taking 40 or 50 wads of dirt and packing them together until they had a nice round ball; then they would roll it out and deposit it on the mound. I, of course, cannot rule out the possibility that this behavior has a strong hereditary component contributing to its origin, much as is the case of the typical ball formation among dung beetles. In support of my contention that this was a truly creative act, I can only say that I have examined thousands of mounds of wild rats not exposed to the extra intense forces producing social withdrawal in my enclosed population. Never did I observe this ball formation under these more natural conditions, where low velocity rats are not likely to survive very long.

Other instances of developing novel and useful behavior only by rats with reduced social velocity have been observed. In a search for the possible reasons for this proclivity by moderately withdrawn rats, I have screened rats of varying velocity in an apparatus which records the duration and sequence of a number of behavioral states such as sleeping, grooming, eating, drinking and locomoting. High velocity rats tend to have much more order in the sequences. On the other hand, the lower velocity individuals exhibit greater randomness of their sequences. For them, one can predict much less well what the next behavior will be on the basis of the ongoing one. As velocity lowers, the chances increase that there will arise some new ordering of behaviors that might be advantageous. From such observations I have concluded that a flowing back and forth with regard to degree of social withdrawal or reduction in velocity is conducive to creativity. The reduction of velocity permits dissolution of former fixed sequential activities and permits new combinations of behavioral states. Reduction of the pressures which led to social withdrawal permits increased velocity and a fixation of the new sequence which arose during the lowered velocity state.

To the extent that these insights may have applicability on the human level, it necessitates placing a new perspective on the general issue of mental health. Fostering high velocity and heightened involvement in social interactions promotes the acquisition of that knowledge and those sequences of behavior most conducive to adequate functioning under the conditions most prevalent in the here and now. Increased social withdrawal and reduction of velocity promotes dissolution of prior patterns of behaving and thinking and their replacement by different sequences. Then the opportunity to resume social involvement, to increase velocity, permits fixation of the new patterns

evolved while in the more withdrawn state. Whether these new patterns of behaving are judged as creative by society depends upon their functional utility under altered circumstances, or whether they may contribute to producing altered conditions deemed desirable by society. From the point of view of augmenting the prevalence of creativity, the concept of mental health must incorporate the desirability of fostering the shifting up and down the scale of velocity, even though this may involve some expression of behaviors judged undesirable from other points of view.

THE "MYTHEMATICAL" SOCIAL POOL GAME

Although considerable empirical data buttress the concept of velocity, we may appreciate its origins and implications better by examining a diagram of the "mythematical" social pool game, a crude representation of a more complex mathematical model [9].

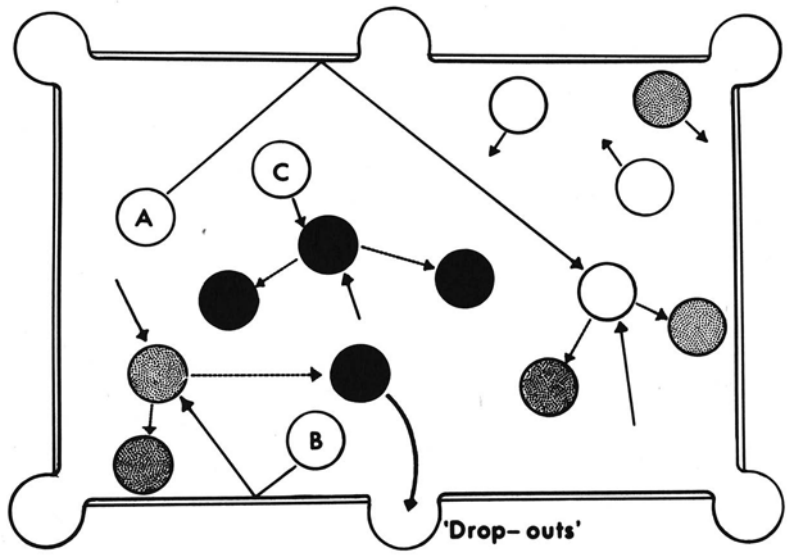


FIGURE 5 - THE "MYTHEMATICAL" SOCIAL POOL GAME

Consider several billiard balls on a table (Figure 5). Each has certain attributes. Each moves at a constant velocity, as if propelled by some inner force. The physical diameter of each is equal to that of every other ball. All move within a fixed space or area. How often one ball will on the average collide with another will depend upon these three factors, velocity, diameter and area, in relationship to the number of balls present in the area. Furthermore,

each ball from time to time develops a need state for contacting some other ball in an equivalent need state. Ball "A" with a bent arrow indicating its path of movement represents such a ball in the need state of encountering another ball in a like state. As shown, it does encounter such a ball. Each then gains from the encounter; each enters a state, which may be designated as gratification, that lasts for some time after the encounter. Residing in this state of gratification is indicated by the balls becoming stippled. After a specified period of time elapses, each of the stippled balls will complete its stay in the gratification state and return to the state of needing further contact with other balls.

One such ball, "B", by chance encounters a ball which is still in the gratification state from a prior satisfactory encounter. This latter ball remains uninfluenced by the encounter with "B"; it remains stippled. However, its failure to interact appropriately to the needs of "B" transforms "B" into a state of frustration indicated by the ball becoming black. In like fashion, when another ball, "C", meets a ball in the frustration state, it too will be thrown into the state of frustration, in which it will remain for some period of time before returning to the original need state for contact. At all times every ball is in one of three states: in need of contact, gratified from a satisfactory contact, or frustrated from an unsatisfactory contact. Purely by chance some balls will be frustrated more often than others. The more these balls are frustrated, the more they will try to escape from the field, the area within which meaningful contacts might occur. They seek the side pockets of their area of habitation. Here they are not visible to view; their "dropping out" leads to a lowered estimate of their velocity in terms of the total path traversed in the contact opportunity area over extended periods of time.

Furthermore, we can assume other attributes of these balls. Each contact involves a particular repertoire of actions by each contactee toward the other, if the one or both in the need state for contact are to be rewarded, i.e., to be precipitated into the state of gratification. When any ball in a need state for contact is not responded to appropriately, because the ball it contacts is in a refractory state of gratification or frustration, it will by this inappropriate response not have its own actions rewarded. As a consequence, its behavior will become somewhat deviant as it emerges again into the need state for contact. Thus, in proportion to the number of frustrating experiences to the number of gratifying ones, a ball will exhibit more deviance of behavior as frustrating experiences increase. As a consequence, the members of the group will vary with respect to both velocity and deviance of behavior.

Two other variables are involved, the intensity or strength of contact and the number of individuals inhabiting the area. Now let us assume that the balls have acquired the property of replicating themselves and of possessing a mechanism for passing to succeeding

generations properties which will increase the likelihood of expression of appropriate behavior. The most important of these relates to the intensity of involvement at the time of contact. Depending upon the number of balls in the area, there is a specific intensity of contact which will maximize the amount of time spent in the state of gratification. This arises from the property of duration of remaining in refractory states of gratification or frustration being proportional to the intensity of contact. There is another peculiar consequence of life within such a system of contacts: balls will attempt to maximize the amount of time spent in the state of gratification. This attempt has the consequence of producing an equivalent amount of frustration. Since this is the nature of life, the genetic basis of physiology for its proper functioning comes to demand experiencing of equal amounts of frustration and gratification. Alterations from optimum group size, that is any change in the number of balls on the pool table of customary size, leads to an imbalance in fulfilling these two needs. When too few balls are present, the average ball will experience too little of both gratification and frustration. When the number of balls in the area reaches the square of the optimum number, every individual will essentially be frustrated as a result of every encounter since every other ball is essentially always in a frustrating refractory state. In this situation, every ball will develop maximal withdrawal, maximal reduction of velocity. No ball will have any awareness of any associate, even though they are crowded closely together. So far our experiments have not fully validated this conclusion, but they point in the direction of its correctness.

We call such balls by various names. Some are called mice, some rats, others man. Even fairly casual observation of such balls, each with its species-specific attributes, confirms the general validity of the above formulation. I call such simulations of more complex phenomena "Mythematical Games". This term reflects a core conviction of mine--any particular expression of behavior as a sample of a wide range of possible variation is relatively meaningless, and even unintelligible. True appreciation of individual isolated episodes comes only from viewing them against the backdrop of a conceptual formulation never ever expressed as such. In this sense the concept is a myth which forms the only reality.

In a later section we will need recourse to a simple expression of one aspect of the above mythematical formulation.

Let: A = area inhabited by N individuals

v = average velocity of an individual through A

d = target diameter of an individual

Where the individual is considered as a ball the target diameter is simply the diameter of the ball. In general, d encompasses any attribute which biases the probability that an individual will be detected and contacted by associates.

μ = communication constant reflecting the likelihood of contact

Then: $\mu = dv/A$

when a species is in evolutionary equilibrium

$\mu = 1.0$

that is to say: A = 1.0 and both d and v have the value, $(A)^{\frac{1}{2}}$. Each will change over time symmetrically with A. When I say that a species is in evolutionary equilibrium, I mean that there is an optimum number of individuals inhabiting each unit of area, A. As a secondary abstraction, and a more meaningful one, evolutionary equilibrium connotes an appropriate number of contacts per unit time per individual to maximize gratification, and as a by-product to produce an equivalent amount of frustration.

THE CONCEPT OF THE OPTIMUM (BASIC) GROUP SIZE, N_b

The previous formulations indicate the necessity for a constant group size inhabiting a particular sized area. When we look across the many species of mammals surviving today, there is obviously a wide range of optimum group sizes. Some species customarily lead a fairly solitary way of life, others live in various intermediate sized groups, and some form very large aggregates. However, there is one particularly common optimum sized group which demands our attention. This is the one consisting of 12 individuals. We have to look far back into the roots of mammalian evolution for its origin, although much of the picture I will develop may be seen in contemporary species which reflect earlier evolutionary stages.

In Figure 6 each dot represents the center of the range of an individual mammal of any species which has the capacity of establishing a single or several closely neighboring homesites. For simplicity's sake, let us think of a single homesite in the exact center of each individual's range. If we take any typical individual and represent the extent of its range by a circle, it may be seen that the range of every individual will overlap those of several associates. The reason for this lies in certain peculiar properties with which every individual moves through its range and responds to resources located in it. Many excursions terminate near the central homesite. Per unit area, fewer and fewer terminate at increasing distances from the range center. Were individuals maximally antagonistic, to the

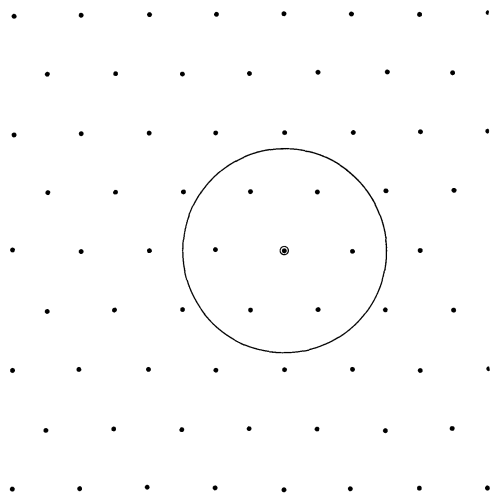


FIGURE 6 - THE IDEAL DISTRIBUTION OF HOME RANGE CENTERS OF ASOCIAL MAMMALS

The range of each individual about its center has the extent of the example shown by the circle.

extent of there being no overlap of the ranges of neighbors, the total population would make very ineffective utilization of resources, since no individual often visits regions in the outer portions of their respective ranges. Evolution, abhorring such inefficiency, has permitted the development of mutual tolerance, implemented by appropriate spacing behaviors, to the extent that the degree of overlap of adjoining ranges will permit an equal utilization of resources over all space inhabited by a population. There is a specific mathematical equation, that of the bivariate normal distribution function, which adequately describes the distribution of responses of an individual over its range [9,10]. This equation includes a parameter, σ, here a measure of distance such that the radius of the home range equals 3σ. When animals attempt to maximize distance between home range centers, and to achieve the most effective use of resources, the distance between the home range centers of any two neighbors will be 2σ.

With this degree of overlap of neighboring ranges, each individual will occasionally encounter neighbors. To the extent that individuals come to know each other, a force of attraction counteract-

ing the more primitive dispersion resulting from antagonisms will come into play. Animals will begin to clump about those individuals, any set of them, whose ranges do not overlap. Individuals whose ranges do not overlap cannot know each other, and therefore cannot be attracted toward each other. The large circles in Figure 7 represent three such individuals. The homesites of their neighbors are represented by dots, squares, or triangles. Each of the three particular individuals we are particularly concerned with will attract to themselves their six nearest neighbors, whose original homesites are represented by dots. Each of the three individuals shown, about whom a condensation of social structure is developing, also has 12 next-nearest neighbors whose homesites are represented by squares or triangles.

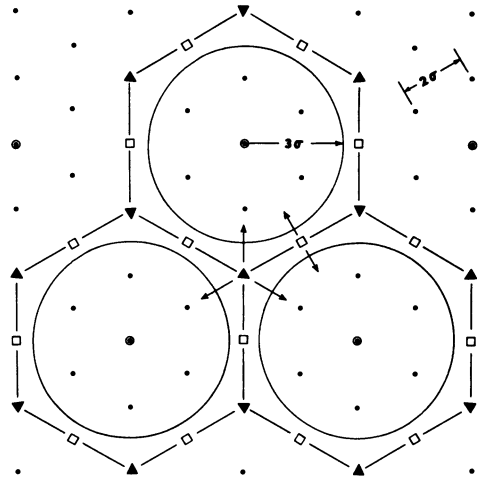


FIGURE 7

CONDENSATION OF DISPERSED INDIVIDUALS INTO SOCIAL GROUPS

◉ = Individuals whose ranges do not overlap and who do not share nearest neighbors. These are alpha individuals.

• = Beta individuals; they form sets of six nearest neighbors to alpha individuals.

□ = γ_1, gamma type 1, individuals, who may be attracted to either one of two neighboring individuals.

▲ = γ_2, gamma type 2, individuals, who may be attracted to either one of three neighboring alpha individuals.

The condensation leads to an average group of 12 individuals with a range of 7 to 19.

Consider one of these neighbors whose home range center is represented by a square. It lies halfway between two of the individuals about whom condensation of the social structure is taking place. It, thus, has the opportunity of becoming attached to either one of them. Let us designate as alpha individuals the ones to whom associates are being attracted. Then it may be seen that each alpha individual has six of these next-nearest neighbors, each of which has a 50-50 chance of being attracted to him. On the average, each alpha individual will have three of these next-nearest neighbors attracted to himself. By like reasoning, each of the next-nearest neighbors, whose homesite is shown by a triangle, has a one-third chance of being attracted to each of its three alpha neighbors. Since each of the alpha individuals has six such next-nearest neighbors, he will on the average attract two of them to himself. Thus, by this condensation process, the average social group will come to be comprised of 1 + 6 + 3 + 2 = 12 individuals.

At first, such groups are hardly recognizable as such. The alpha individuals's neighbors merely shift their homesites slightly toward his. Over considerable evolutionary time, the group further condenses until all members live at the same place or may even move together through their now common range. Among the many species of mammals which have developed an optimum or basic group of 12, there is the Norway rat, several species of primates and man himself. For the purposes of designating the optimum group size, socially immature individuals do not count. These immature individuals must mature within the social context of an approximately optimum sized group, but for our present purposes they must be considered as comprising essential background noise.

Maturing individuals will eventually enter the adult ranks. They will tend to remain as members of the parent group as long as possible. Some will replace older members which die. But if survival is sufficiently high, the size of the group will gradually increase to more than the optimum number. A particularly critical point is reached when the number of individuals in the group attains one less than twice the optimum size. It is at this point that the members of the group become particularly sensitive to the increased frustrations of life within the context of a larger than optimum sized group. The normal response at this point is for the group to split. One half can remain in the original area, while the other half must seek a new area for colonizing. In time, all suitable terrain available to the species will be filled up; then disease, predation, and intra- and inter-group strife come into full play to bring natality and mortality into balance.

In only rare instances has any species other than man been able to overcome this barrier to further development. Outstanding is the example of baboons. Through the development of genetically determined sexual dimorphism, the optimum group size has been able to expand from

12 to 24 adults [19: p.335-367; 20,22]. Presumably this role differentiation, making possible an increased group size, has also been accompanied by the evolution of more effective means of extracting energy resources. We can see a similar process in operation among the Hutterites of South Dakota, Montana and Canada. With upwards of four children per family, the optimum total group including children appears to be about 75. This is indicated by the fact that when the total group reaches 150 it divides and one half must seek a communal farm elsewhere [1: p. 298, 32,33]. This indicates that the optimum group size has increased to 24. There is little reason to anticipate that this increase has been brought about by genetic changes. We must, therefore, conclude that role differentiation among the Hutterites is just sufficient on a cultural basis to make the overall group essentially two groups of 12 sharing the same area through restricting with whom it is appropriate to interact. Then, in so far as any individual is concerned, the number of his interactions per day will remain much as it was within a primitive hunter-gatherer group of 12 adults. No doubt the Hutterites have been able to approximate the Eden state of incipient agriculture. Archeological studies of Jarmo in Iraq of nearly 10,000 years ago indicate that this early agricultural society was able to develop and tolerate a total group size of 150 individuals [4]. And yet, by this approach to an Edenic way of life, the Hutterites confirm my suspicion of the inevitability of the origin of behavioral deviation and mental illness as an unavoidable consequence of group life [2: p.638].

But confirmation of this inevitability is not the reason for my particular search. Rather, it has been to try and determine if there may be a logical basis for determining what the optimum upper number of man on earth may be.

CONDENSATION OF HUMAN SOCIAL GROUPS AND AN EMERGENT CONCEPT OF CULTURE AREA

Man like most creatures is intrinsically conservative. He obeys what has been called "Romer's Rule".* This law holds that even when the weaker groups of a species are excluded from former terrain, they search for a new opportunity for reestablishing the former way of life; but in so doing they may be forced to adapt genetically or culturally to some unanticipated circumstance. The strong remain where few crises arise demanding change and adaptation--they remain firmly traditional. The weak from necessity must become creative to survive.

* C.F. Hockett and R. Ascher state Romer's Rule as: "The initial survival value of a favorable innovation is conservative, in that it renders possible the maintenance of a traditional way of life in the face of changed circumstances" and in following discussion they emphasize that weaker or excluded groups, or those less well able to maintain fully the traditional way of life are more likely to be innovative [23: p.72].

Romer's Rule proposes that there is survival of the weak; survival of the meek. This proposal conforms to my formulation that rejection and withdrawal preceding reestablishment of a normal way of life is essential to creativity.

Now let us look back upon primitive hunter-gatherer man, who for countless millenia had followed a very simple and extremely slowly changing way of life. In so long as new terrain remained for groups budded from former ones to enter, there was no impetus for radical change. The old way of life could be reduplicated. However, at some point in time, extensive land masses became filled with these small bands containing an average of 12 adults and 18 children each. Each band roamed over a range 3σ in radius. Although each band might temporarily reside at several sites, the site most frequented lies at the center of the range. The points in Figure 8 represent these most frequented sites, which will simply be referred to as the village site. Just as with the home range centers of small asocial mammals, the village sites must be uniformly distributed with a 2σ interval between them in order to achieve the most efficient utilization of resources by a large population of bands. Once this state of affairs had developed over extensive regions, there existed no further place to go when groups increased to a size dictating that they split and one move away. They then faced a real dilemma. The need to maximize gratification demanded that there be a constant area for each group in order that the appropriate number of contacts per unit time would be realized. Since this need is grounded in physiology determined by heredity, this means that in so long as heredity remains essentially unchanged, there must remain as an invariant a particular sized area per adult individual.

Even though there was no more space to invade, man's ability to maintain natality greater than mortality tended to force the size of groups to increase. The conservative response was to increase mortality by inter-group fratricide or intra-group infanticide. Obviously this is an extreme oversimplification, but it does reflect the character of the conservative traditional response. At some point in time, some downtrodden group or groups discovered a new kind of space, a new kind of area they could move into. I shall call this "conceptual area". For the group to double in numbers while residing in the same physical space, it must acquire a conceptual area equivalent to its physical area. In this sense, conceptual area amounts simply to the acquisition of values and codes which permit role differentiation to the extent that, even in a double-sized group in the original physical area, meaningful social contacts would continue at the rate necessary to maximize gratification. In all probability, the first major role differentiation involved a culturally defined sexual difference in modes of extracting food and related resources. In fact, it was probably the need to discover more efficient means of extracting such resources by a denser population that first precipitated the development of the new roles and the new technologies

which comprised the discovered conceptual area for invasion and exploitation.

Discovery of any new parcel of conceptual space requires retreat into another kind of space, the world of fantasy, a creative space. By analogy this creative space is involved in a creative communication constant, μ', where

$$\mu' = d'v'/A'$$

Here A' is the creative fantasy space, where the withdrawn individual generates objects for interaction out of his store of memory traces. These may be fantasied other people, but may just as well be any rearrangement of information which he finds pleasing. v' represents a sort of velocity with which the individual moves among the objects of his intellectual creation. Similarly, d' represents a sort of target diameter of the fantasying self and of the ideational objects created which permit them to contact and interact. The most intimate and intense of these fantasied interactions culminate in an intellectual orgasm, the eureka experience of the truly creative episode. Retreat into fantasy area by some members of the group is a prerequisite to developing the concepts which form the structures which force conceptual area to expand in harmony with population increase. We need feel no pity for individuals who have withdrawn into fantasy area. As many of you know from personal experience, life there can be lush and rewarding. What society has to provide is the means for enticing such individuals to return to the so-called normal reality of social intercourse where created concepts can be subjected to scrutiny and accepted if they prove to be a valuable addition to the existing conceptual area. For these concepts to warrant acceptance they must contribute in some way to role differentiation or to the development of resources or to their more efficient extraction. With this essential aside, let us return to the problem of conceptual area, or we may call it conceptual space to maintain a feeling of consistency with the title of my presentation.

With the first acquisition of a conceptual space equivalent to that of the physical space already occupied, man emerged as truly Homo sapiens. From that point on, man could continue to justify this appellation by making sufficient additions to conceptual area as population increased to maintain constant the total area available to each individual. This is my basic hypothesis: increases in conceptual area must keep approximately abreast with increases in total population.

It is impossible to maintain this process solely within the confines of the local group occupying one of the village sites represented in Figure 8. At some point in time, at some point in the process of increasing conceptual space, there must arise a sociopolitical union of the village sites, each of which then contains

more than two times the original optimum number. By this time the typical village will already have participated in the emerging Agricultural Revolution. Each site will have become more firmly fixed in space. Condensation or crystallization of the social structure by such union must proceed without the shifts of location that characterized the much earlier formation of compact groups from dispersed individuals. This restriction on shifting requires that the ranges of influence of village sites, about which this social condensation develops, must be packed as closely as possible without overlapping, since such overlapping would produce initial undesirable disharmony.

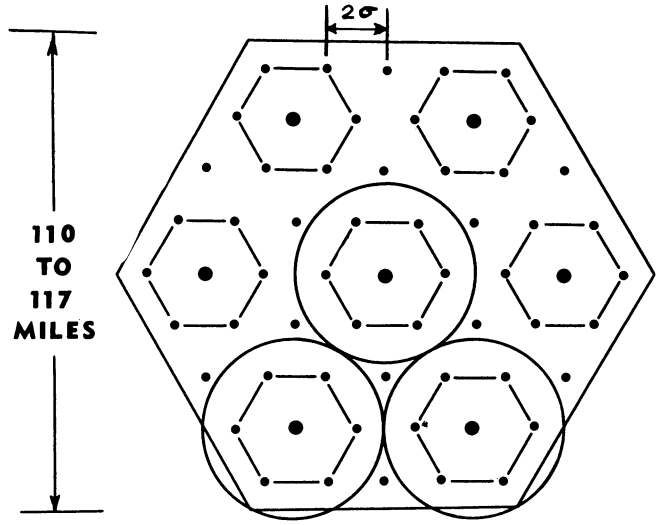


FIGURE 8 - FORMATION OF UNIFORMLY SCATTERED VILLAGE SITES INTO SEVEN DISTRICTS WHICH LATER COALESCE INTO A SINGLE "CULTURE AREA"

Village sites are 2σ distance in miles apart.

◉ = Village sites which will become district capitals.

The radius of influence of a district = 3σ, where $\sigma = 7.5$ miles, as in western South America and Mesoamerica south of Mexico City the culture area covers 11,840 sq. miles.

The ranges of influence of three such villages are shown as circles in Figure 8. It will be noted that each such range having a 3σ radius encompasses the locations of six other village sites. Together they form a "District". With further increase in total population over an extensive area, development of messengers and traders as specialized new roles forming a part of the increased conceptual area permits adjoining districts to be bound together in a single socio-political union. The topography of the distribution of districts makes such union most practical and efficient, if one such district dominates its six nearest neighboring districts. To show the relative extent of such an assembly of districts, a hexagon may be circumscribed about the ranges of influence of the peripheral six districts. This is the outer hexagon shown in Figure 8. It will be noted that I have included a range of 110 to 117 miles as defining the distance across this complex, which I define as a "culture area". Obviously, I have adapted this term "culture area" in the present specific meaning from its more general usage by Kroeber and others [25]. What is not apparent is the origin of the distances representing the more common expected diameter of the hexagon enclosing the culture area.

I can only trace briefly the origin of this estimate of distance. In 1962 I had the opportunity of spending a year at the Center for Advanced Study in the Behavioral Sciences at Palo Alto, California. Although I did complete my major theoretical work on the social use of space at that time, I decided to spend most of my time searching the literature relating to population, archeology, anthropology and history for insights about man's evolving use of space. In this process I scanned a fairly large body of literature and examined several hundred books and articles in detail. Somewhere along this process, which has continued to the present, I became impressed with the frequency of encountering significant socio-political unions, the diameter of whose physical domain was slightly over 100 miles. Early in 1967, while I was immersed in the literature on the Calusa Indians of Florida, the present formulation of culture area crystallized in my mind. If there were any merit to this concept, some initial confirmation of its possible validity might be revealed by examining the distances between district, provincial and national capitals of Central America and northern and western South America. If the theory is correct, only certain distances would be anticipated, with a specific number of each kind of distance. Furthermore, each distance could be translated into sigma units of the range of the average village. The analysis of 386 such distances between actual cities gave an estimate of 7.5 miles for sigma. As indicated in Figure 8, the distance between the centers of adjoining village sites is 2σ. From this it may be calculated that the distance across the hexagonal culture area is 15.59σ. With a σ of 7.5 miles, this distance across the culture area is 117 miles and includes a total area of 11,840 square miles.

According to the present theory, the culture area forms a mold which will be preserved and reflected in much later spheres of socio-political influence. One such type of sphere of influence is represented by the central place theory of economics which identifies hierarchical overlapping spheres of influence of successively greater scope within which a single city serves as a focus for and encompasses all smaller areas of influence. Woldenberg's recent synthesis is particularly instructive [40]. One of his examples is that of Christaller's study of eight such spheres of influence dominated by Strassburg, Frankfurt, Stuttgart, Zurich, Munich, Nuremberg, Linz, and Pilsen. Each presumably represents the long aftermath of culture areas established several thousand years ago. These eight cities provide 13 inter-city distances with an average of 110.5 miles, which I have rounded off to 110 miles, which gives an estimate of 7.0 miles for the σ range parameter of an original village site according to the present model as shown in Figure 8.

These two examples of estimating the range of a village merely serve to indicate the quite crude methodology for making this intuitive hypothesis of culture area more specific. Other much more general indications of support for the idea are provided by examples which seem to conform to the hypothesis. For example, there are the seven Basque "nations". These "nations" correspond to the districts of the present formulation. Similarly, there are the seven sheikdoms of the Trucial Coast, or we can note that the Romans divided what is modern Portugal into three administrative units, each of an area comparable to a culture area.

All of this focus on the concept of culture area was directed toward establishing a basis for predicting the upper optimum limit of world population. For this effort to be successful, it was necessary to establish how far population growth could continue within a culture area as a consequence of expansion of conceptual space that did not go beyond inclusion of socio-political union that was confined within the culture area itself. One of the initial clues involved the report that Alvarado met a force of nearly 30,000 warriors when he invaded Guatemala. Portions of my earlier theory on the evolution of social groups suggested that 7/12 of the basic social groups represent the more dominant segment. If the maximum fighting force at full development of the culture area as an isolated independent socio-political unit included 7/12 of the adult males, it would take a total population of over 200,000 persons to muster such a force.

Attaining this number involved several doublings of the population within the culture area and consequently several doublings of the conceptual area. Looking back to the time when the culture area was first fully settled within primitive hunter-gatherer groups, the total population included 61 bands, each on the average with 12 adults and 18 children, making a total population of 1,830 individuals.

Seven successive population doublings pass through totals of 3,660; 7,320; 14,640; 29,280; 58,560; 117,120 to 234,240. We may take the latter as the upper optimum population of a self-contained culture area. Confirmation that this number does represent the terminal phase of the isolated culture area is provided by the fact that in 1745, the time of the Battle of Culloden when the Scottish people were finally and firmly brought within the larger socio-political union of the English Crown, there were 245,000 persons inhabiting the seven crofting counties (districts of my terminology) of Highland Scotland. I cannot at this time be exhaustive in this analysis; at each level of analysis I only continue the search long enough to feel that I am on the right track.

THE OPTIMUM WORLD POPULATION

In a perfectly uniform terrain, each culture area will be surrounded by six others. Each such set of seven culture areas then forms the basis for a further socio-political union. Such unions form as aspect of the increasing conceptual space which will permit the population within each culture area to double to 468,480. The union of seven culture areas I will call a "nation" (Figure 9). As

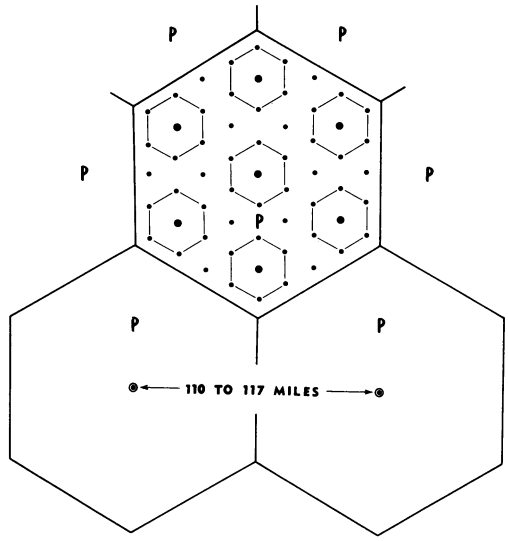


FIGURE 9 - FORMATION OF A "NATION" FROM THE UNION OF SEVEN "CULTURE AREAS". THE CONTAINED CULTURE AREAS BECOME "PROVINCES", P, OF THE NATION.

Table 1.

Theoretical population growth associated with doubling of population with each coalescing of seven of the prior levels of socio-political organization and accompanying increase in conceptual space.*

Socio-political Unit	Number of Contained Culture Areas per Unit	Number of Units	Unit Population	World Population	Theoretical Date
"Culture Area" at "City State" Level	1	2401	234,240	562,410,240	1709
"Nation"	7	343	3,279,360	1,124,820,480	1868
"Empire"	49	49	45,911,040	2,249,640,960	1948
"League"	343	7	642,754,560	4,499,281,920	1988
"World Union"	2401	1	8,998,563,840	8,998,563,840	2008

* This formulation assumes complete similarity of phasing of development over all time over all the world. In a more general application to the real world coalescence of "City States" into "Nations" begins with the local development of a technological-scientific revolution paralleled by comparable increases in philosophical conceptual space.

an isolated socio-political unit, it will include a total population of 3,279,360. By a similar process, seven nations can unite to form an "empire". This union will permit the population of each contained nation to double to 6,558,720 and the empire will therefore contain a total population of 45,911,040. By a similar process, seven empires can unite into a "league". This will permit the population of each empire to double to 91,822,080, and thus the league will contain a total population of 642,754,560. Again by a similar process, seven leagues will unite to form a "world union". This will permit the population of each league to double to 1,285,509,120 and the world union to include 8,998,563,840 individuals. This "nine" billion is the optimum upper world population. This process is summarized in Table 1.*

Completion of this process requires 7^4 or 2,401 culture areas. Since the average culture area covers 11,840 square miles, the world union will include a minimum of 28 million square miles. (It is obvious that the above process of socio-political union could not continue for another round since it would require four times the land surface of the earth to satisfy the spatial requirements of the theoretical 126 billion population). With only slightly less than 47 million square miles of land surface not now in deserts or frozen wastes, this leaves less than 19 million square miles which might continue as primarily the domain of other forms of life. And yet the world population will probably overshoot the optimum population of nine billion, since it seems unlikely that population increase can be brought to a halt before it reaches 13.5 billion. This amount of overshoot will place extreme burdens on man to preserve adequate communities of other forms of life, particularly during the period required to decrease again to nine billion. Our sceneria for the future should, at a minimum, extend through the period of overshoot until the optimum upper population is reattained.

TO SUMMARIZE: Man stands unique among animals in learning how to bypass the strictures placed by limitation of physical space on further population growth. He has made this escape by discovering how to create conceptual space, the total information pool generated by man from which rules, codes and theories may be condensed which permit more effective coping with the physical and social environment. In particular, this process of increasing conceptual space as population increases permits each individual on the average to become involved in the same number of social interactions per day as held true in the earlier times, when life was primarily confined to experiences within a hunter-gatherer band of 12 adults and their associated children. To continue enlarging conceptual space requires involving more and

* In the present instance, dates are based on a slight modification of the von Foerster equation to one in which each doubling of the population requires half the time as the prior doubling; otherwise, the same data are presented elsewhere [15].

individuals in a common communication network. Socio-political union enhances the enlargement and effectiveness of such networks. Such union will continue until the entire world population becomes incorporated into a single network. This point will arrive when the world population reaches nine billion. For this reason, nine billion is set as the optimum world population in which individual human beings serve as the primary nodes and the primary links in the communication network.

CONCEPTUAL TARGET DIAMETER AND VELOCITY

I have earlier indicated that where life was primarily confined to functioning within physical space, contacts culminating in gratification and frustration are influenced by a communication constant, μ, where $\mu = dv/A$. By analogy contacts relating to life within conceptual space are similarly governed by another communication constant, μ'', where $\mu'' = d''v''/A''$. d'' represents conceptual target diameter, that property or consequence of the store of concepts which the individual has been able to acquire and utilize for both mining resources and control of contacts with associates. Similarly, conceptual velocity, v'', represents a kind of movement through the conceptual space of available information in a manner which permits sufficient acquisition of concepts to maintain the individual's target diameter, or to enlarge it as the population increases or as the number of others met increases. Conceptual velocity represents the cortical processes of scanning or exploring conceptual space, A''.

The evolution of the genus Homo involved a more rapid increase in cortical mass in proportion to body mass than had been true among other mammals. This increase permitted each individual within its own life span and solely by its own experiences to learn more effective ways of coping with the environment. Then, as Homo sapiens emerged within the genus, increase in cortical mass gradually ceased. This cessation was brought about by the gradual acquisition of the capacity for creating conceptual space and the ability to pass most of its structure on to the next generation. At the time when we may say that Homo sapiens had clearly emerged as a cultural species, as distinct from the physical attributes which define him as a biological species, the conceptual space or conceptual area available to each individual became equivalent to the physical space available to him. At this time, A = A''. As we will shortly see, this time may be approximated as 38,710 B.C.: a time at which, if the world of man were developing uniformly, there would have been 146,461 primitive bands at the 12-adults-per-band stage. With their children they formed a total population of about 4.4 million. Since man as a truly cultural animal, one with the ability to generate conceptual space, likely emerged first in the more crowded central portions of his range, the actual date of his first cultural emergence must have been somewhat before 40,000 years ago. In any case, at this time of emergence man must have been in equilibrium with his conceptual space.

Therefore,

$$\mu'' = d''v''/A'' = 1.0$$

At this time it may also be considered that d" = v". It follows that both d" and v" = $(A)^{\frac{1}{2}}$.

At some time in the distant past, man utilized his cortex to the extent of incorporating a unit of conceptual space equivalent to the physical space in which he lived. At this time, we may view the actual diameter of the head as representing the degree of utilization of the cortex and thus equivalent to conceptual target diameter. Later enlargements of conceptual target diameter thus may be depicted as enlargements of the head, while the rest of the body remains constant in size (Figure 12). Where d_μ stands for diameter of a sphere equivalent to that of the utilized cortex* then:

$$d_\mu = 2(A'')^{1/6}$$

Obviously, there will arrive a time at which maximal utilization of cortical mass will be attained. Since population growth, which permits realization of individual potentialities, depends upon continual expansion of conceptual space, it follows that, when maximal utilization of cortical mass is reached, any further increase in numbers will lead to a decline in effective realization of potentialities, since the extra individuals will impede acquisition of relevant information. By some strange coincidence, it looks as though maximum use of the cortex will actually arise at the time

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* Let r_μ, d_μ and A_μ represent radius, diameter, and volume of a sphere representing utilized cortical mass. And employing " = " in the sense of "proportional to", we have: $A_\mu = r_\mu^3$, $d_\mu = 2r_\mu$; and from the logic in the text $d'' = (A'')^{\frac{1}{2}} = A_\mu$. Therefore: $A_\mu = (d_\mu/2)^3$; $d_\mu = 2(A_\mu)^{1/3}$.

Substituting $(A'')^{\frac{1}{2}} = A$ in the latter equation, we have $d_\mu = 2[(A'')^{\frac{1}{2}}]^{1/3} = 2(A'')^{1/6}$. d_μ's at times of sequential doublings of A" were calculated. These, with slight modifications for artistic purposes were utilized in the preparation of Figure 12. It follows that $d_\mu = 2(d'')^{1/3}$ or $d'' = [d_\mu/2]^3$. The original concept of target diameter [9,10], elaborated this contact enhancing factor through a transition from mere body width or diameter to involvement of other attributes, such as plumage or stance, which increased the likelihood of two individuals interacting. Thus, target diameter comes to include any force or condition or process enhancing contact. Ability to acquire and utilize concepts, in the sense of d" as representing conceptual target diameter, in like fashion influences whether or not two individuals will interact.

of reaching the optimum upper level of population. However, it will be necessary to develop the formulation a little more before returning to that point.

We also need to inquire further as to the meaning of conceptual velocity. If the logic being developed here is correct, movement in physical space and movement in conceptual space should have much the same properties. You will recall from the earlier discussion of making empirical operational measures of velocity in mice, that our procedure was to record how often each individual was noted moving through its available physical space. All such movement is noted during episodes of locomotion between which the mouse was asleep or engaged in some nonlocomoting activity. The final index of velocity results from the interaction of two variables, how frequently episodes of locomotion begin and how long they last. We shall here only be concerned with the latter. Each episode of locomotion is a particular instance of the behavioral state of moving through the physical environment. When a large sample of such behavioral states is examined with regard to their duration, it is noted that all last at least for a length of time, T; and there is some maximum duration beyond which no instance extends. Then the span of time from the end of T to the maximum duration may be divided into a number of class intervals of length, t, and the number, N, of behavioral states, β, of each class interval of duration tallied. When this is done, as we have done for many large samples obtained in our studies of rats, N as a function of T + t forms a negative exponential curve as shown in Figure 10. This is the most common pattern. Such results mean that after any β has continued for a duration of time, T, there is a constant probability, p', that it will terminate in the next unit of time, t, regardless of how long it has already lasted.

However, if we select a sample of episodes of locomotion in which each instance was preceded by a relatively long period of other activities or states than locomotion, a pattern having a much longer mean duration is revealed. The change in pattern in the shorter durations is that shown by the trend of the open dots in Figure 10. The interpretation of this change is as follows: Beginning at the termination of time duration, T, there is a marked inhibition of the impulse that terminates the behavioral state. The longer the behavioral state continues, the less strong is this inhibitory influence, until, at a time denoted by the intersection of the two lines of Figure 10, it no longer functions. Beyond this time the constant probability of the behavioral state terminating in the next interval of time, t, holds as in the first pattern described above. Although this description is presented here because it describes the behavioral state of locomotion from which estimates of velocity are obtained in the free-ranging situation of animals as members of social groups, I wish to point out that this transition from the first to the second pattern adequately describes the whole repertoire of behavioral states in the rat. It holds for the behavioral states of eating,

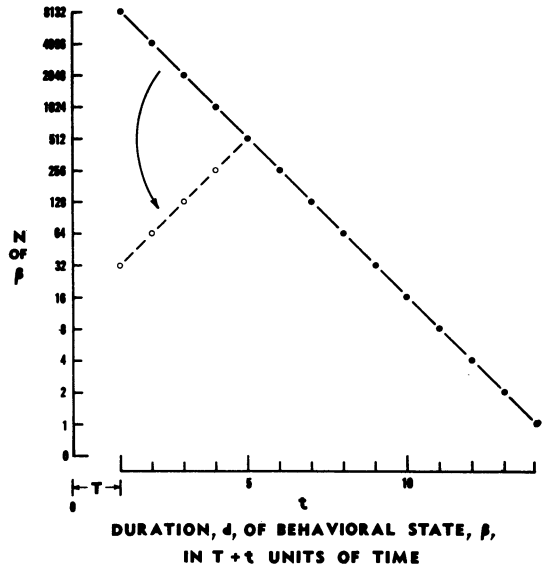

FIGURE 10

THE DURATION OF BEHAVIORAL STATES

Pattern One is that of the solid points only.

Pattern Two has a shift of the shorter durations to that shown by the open dots. Shift from Pattern One to Two produces a doubling of the average duration.

drinking, self-directed activities we pool under the general designation of "grooming", as well as for three distinct kinds of sleep. In fact, it appears that we have discovered a basic pattern of functioning of the central nervous system.*

If this is so, it should apply to behavioral states in man involving the elaboration or entrainment of concepts as a category of behavioral states. Every written paragraph represents an instance of such a behavioral state. The duration of paragraphs may be mea-

* Our full formulation of the CNS control of occurrence, sequence and duration of behavioral states based on our studies of rat behavior remains to be published. Essentially, we have been able to calculate the probabilities of functioning of four signals which permit a fairly comprehensive description of changes in behavior over time. One governs initiation of behavior; two, its terminations; and the fourth, the likelihood of entrainment.

sured as the number of letters each contains. Two samples were selected to explore this problem. One consisted of 3,198 paragraphs selected from about 7,000 pages of literature relating to population and mental health. These paragraphs were judged to include particularly cogent formulation of theory or insight. This sample conformed to the second pattern described above and had an average duration of 826 characters. The second sample consisted of 1,171 paragraphs, nearly the whole book, of Norbert Wiener's "The Tempster". This book was selected because we have good reason to believe that Wiener ranked among the top in recent times in being able to elaborate complex conceptual sequences, and yet in this book he was resorting to an age-old device of storytelling. Although N of β as a function of T + t also conformed to the second pattern, the average number of characters per paragraph was much less, only 396. It is obvious that storytelling forms a distinct behavioral state from that of the formulation of concepts into complex insights. But of much greater importance here is the confirmation that the behavioral state which reflects velocity in physical space has a similar basis in central nervous system function as the behavioral state which reflects velocity of movement through conceptual space.

CULTURAL REVOLUTIONS AND THE INCREASE IN NUMBERS OF MAN

Von Foerster and his colleagues have made an analysis of the numbers of man on earth based on the past 2,000 years [38]. This analysis is most cogent for the present inquiry. In essence, they found that each successive doubling of the population required only half the time necessary for the prior doubling.* Presumably this characteristic of population increase extended far back through the history of the species, at least as far back as the time when communication between contiguous bands enhanced the ability of the members of each band to cope with the contingencies of their physical and social environment. Likewise, this process leading to a continually shorter time between doublings of the population will presumably continue for some time into the future. However, as they point out, this process cannot continue for very long into the future, because, if it does, each successive doubling will be requiring an extremely short time, nearly infinitely short. This time, t_o, at which the population becomes unbounded, they term "Doomsday" and calculate as 2027 A.D.

Doomsday has several closely related implications. It means that the unique process of population increase, which sets man off

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* The von Foerster equation [9,10] for calculating the total population at any time τ, the number of years before 2026 A.D. (the date at which the population will go to infinity if the pattern of increase over the past 2000 years continues), is $N = 1.79 \times 10^{11}/\tau^{0.99 \pm 0.009}$. Since the exponent of τ could be at least 0.999 we have considered it to be 1.0 in the interest of symmetry.

as a cultural species as distinct from his existence as a biological one, must soon terminate, unless he is to continue as only a biological species. It follows that Homo sapiens must cease as a species set off by a set of characteristics which to date have made him distinct. Examination of the past historical process is required to gain an insight into what sort of species he must become if he is to survive. The Von Foerster equation permits calculation of the dates at which a series of doublings of population, as shown in Figure 11, leads to the optimum population of nine billion.

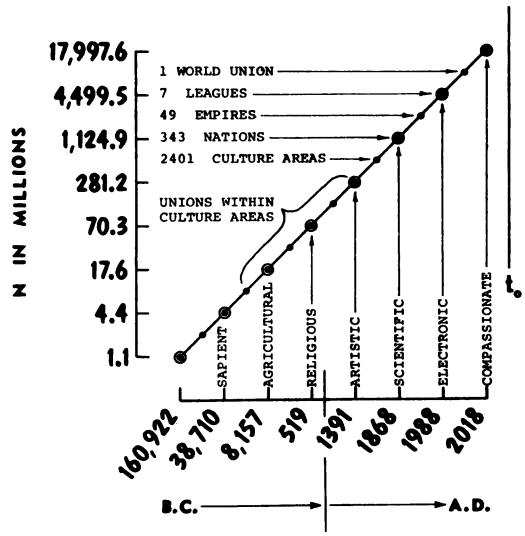

FIGURE 11

THE VON FOERSTER CURVE OF INCREASE IN WORLD POPULATION OF MAN DURING THE SAPIENT DOMAIN OF EVOLUTION

I have already pointed out the reasons for anticipating that, after the origin of man as a cultural species about 40,000 years ago, each doubling of population would require a doubling of conceptual space, A". Conceptual target diameter similarly increases, but more slowly. With every two successive doublings of population and conceptual space, there will be a doubling of conceptual target diameter. These times of simultaneous doublings of population and conceptual target diameter are shown by the circled dots in Figure 11. These seven points (all but the earliest) represent particularly pivotal eras in human history which I will term "conceptual revolutions". Each involves a complete reorientation in the manner in which life and the forces of nature are perceived. Each also involves elaboration of a new strategy for coping with this life and these forces.

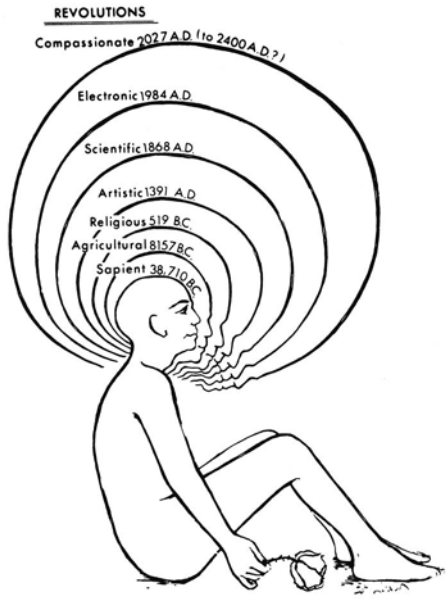

FIGURE 12

THE CONCEPTUAL HOMUNCULUS

I have tried to summarize this whole process of progressive transformations as a "conceptual homunculus". The body of man has remained his earlier biological self, but the degree to which he has effectively utilized his cortex has continually increased. In Figure 12 the diameter of the head is proportional to conceptual target diameter, d". This figure indicates the degree of enlargement of conceptual target diameter at the time of each of the revolutions. Each revolution is given here a single name. However, each should be designated by a hyphenated term reflecting the new "perspective" and the new means of "coping". I will attempt this here, but will leave to others better grounded than I in history, philosophy and futuristic scenarios to characterize these revolutions more effectively:

1. The Traditional-Sapient Revolution of about 38,710 B.C.

Tradition and myth formed the core of the new perspective which permitted the concept of existence to be extended back into the past and, to a much lesser extent, to establish the expectations of the future. Codification of knowledge resulting from experience became the basis of the new means for coping.

2. The Living-Agricultural Revolution of about 8,157 B.C.

The term, "living" as a new perspective implies an awareness of life as a continuing process of birth, development and death, with a dependence of one species upon another. Agriculture, as a way of coping, represents a conscious, but empirical means to mine resources more effectively.

3. The Authoritarian-Religious Revolution of about 519 B.C.

The prior perspective of awareness of life culminated in the conviction that there must be some directed design of the forces guiding nature and the destiny of man. Revealed formulations of the design, which demanded conformity of response to them, comprised the new format for coping.

4. The Holistic-Artistic Revolution of about 1391 A.D.

Further reflection on the question of design produced a pervading feeling of wholeness, accompanied by a tendency to withdraw from the daily routine of life in order to pursue its search. This lead to an apparent dichotomy of designs for coping. On the one hand, we find artistic expressions spanning philosophy, poetry, painting and sculpture, while, on the other hand, this effort culminated in empirical technological procedures and machines--a total reorientation commonly designated as the Renaissance period.

5. The Scientific-Exploitive Revolution of about 1868 A.D.

The Holistic perspective of life lead to a scrutiny of the processes involved in producing change in some portion of the design of nature. We speak of the employment of this perspective as the "Scientific Method". Resultant insights are then transformed into technological devices or procedures for exploiting nature for the benefit of man.

6. The Communication-Electronic Revolution of about 1988 A.D.

There gradually arose a time when personal contact among the members of a much enlarged communication network proved particularly ineffective. Furthermore, the capacity of the cortex to process information necessary to formulate concepts became surpassed. These and similar limitations forced upon us the new perspective of life as an information exchange network and lead to the development of theories and electronic technologies for the transfer and condensing of information as the means for enchanced coping. In deference to Orwell's [31] premonition of a possible course of dystopian derailment of this revolution [39], I have slightly altered the calculated time of this revolution to 1984 A.D.

7. The Compassionate-Systems Revolution of 2018 A.D.

Use of the term "systems" to designate the new means for coping also reflects the new perspective. As an outgrowth of information theory relating to the transfer of information over networks in conjunction with the related development of the field of cybernetics, there arose a body of concepts designated as "general systems theory" [37]. This theory views all of nature and all of human activity as a hierarchically arranged structure of levels of interlocked subset systems in which the process of any particular subset system affects and is affected by other subset systems at its own level, as well as below or above it. We are now moving into an era when this perspective (involving the related techniques and strategies for designing and guiding interrelationships, and for permitting self-organization of subsystems) has become imperative. Selection of the term "compassionate" to designate the perspective of this revolution requires comment.

Roles requisite to the adequate functioning of subset systems will continue to increase in both kind and number. Fulfilling each role requires maximizing the particular set of values requisite to its expression. And yet no one role can be fulfilled unless all the other roles are being adequately met. This means that the diversity of values guiding action will increase. Furthermore, the present era of radical change will become intensified as the character of roles needed to meet new functions also changes. Thus, in the presence of this increased exposure to value conflict, there will be required an augmented awareness of the necessity for others to maintain value sets differing from one's own. Furthermore, realizing one's own functional role requires expenditure of considerable effort in assisting others to fulfill the objectives of their value sets. It is this awareness of, and participation in, the realization of values held by others which characterizes the compassionate perspective. This perspective also includes an awareness that many individuals will experience extreme difficulty in developing and altering their roles and value sets in accordance with the demands of an overall system which is changing and becoming more complex. Holding to this perspective further requires marked attention to assisting others, whom we ourselves might earlier have been, to recoup from this hopefully temporary derailment. In this recognition and implementation of the rights of others, compassion becomes a sublimated and transformed submission. There are other parameters of perspective and coping involved in the compassionate-systems revolution which I will return to after giving consideration to the implications of attaining an optimum upper world population. It will also be noted that I have listed the date of 2027 A.D., with possible continuance to 2400 A.D., as the time of the compassionate-systems revolution rather than the calculated date of 2018 A.D. This is because of its convergence with "doomsday" and the forthcoming transitional period into a new domain for further evolution.

THE SZILARDIAN DOMAIN OF EVOLUTION

Slowing down the present rate of population increase so that the ultimate maximum world population will not greatly exceed the optimum of nine billion requires continuing attention to the present efforts to reduce birth rates. It is quite likely that the rate of reduction in births will be insufficient to prevent an overshoot in population above the optimum. What this overshoot will be cannot be estimated with any reliability at present. I can only hope that this overshoot can be kept to no more than 13.5 billion as a maximum world population. Were the world population to double from the nine billion optimum to 18 billion, it might prove extremely difficult to curtail this process of continuing population increase. I shall assume that the present apparent rate of curtailment of population increase will continue to become more pronounced, to the extent that this slowing down will not culminate in the maximum world population of 13.5 billion until about 200 years from the present.

Whether or not there is a gradual reduction of the world population to the optimal level, we will be faced with the possibility of a continuing and relatively stable population somewhere between 9.0 and 13.5 billion. This continuance of a stable population for a very long time raises some interesting questions. Foremost among these is the problem of conceptual space. So far the entire course of the evolution of man as a cultural species has involved a dual progression of a doubling of conceptual space keeping pace with a doubling of population. Maintaining this historical relationship implies that when population growth terminates, so also will increase of conceptual space terminate. Likewise, the conceptual target diameter of each individual will stabilize at a magnitude equivalent to the square root of the conceptual space available to him. This means that the total involvement of man in relationships and functions will become constant. He will become part of an unvarying static system. The environment of man will have reached its carrying capacity for concepts. Similarly, the habitats of all other species have a carrying capacity for protoplasm or biomass. For humans there will be a carrying capacity for "ideomass", I, in which I is a product of the number, N, times their average target diameter, d".

$$I = Nd", \text{ and } I \text{ is a constant}$$

The full meaning of I remaining constant is far from clear. Comparison with the ecological concept of carrying capacity for biomass provides a lead. The energy resources of the environment can support either a large number of small individuals, or a smaller number of larger ones. In a similar fashion, the world as a habitat for man is fast approaching a time where it can support either an increasingly larger number of individuals, each of which has a decreasing conceptual target diameter, or a fewer number with a corresponding enlarged conceptual target diameter. This leads to three options for

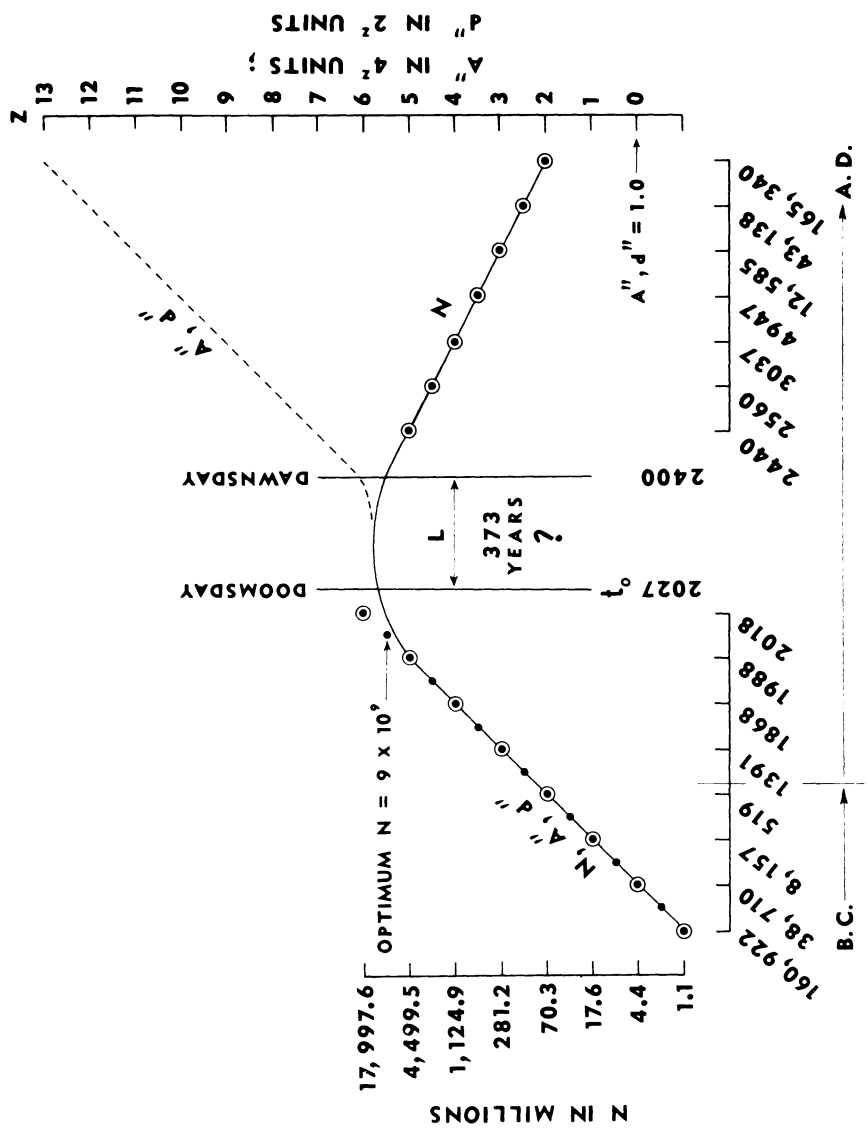

FIGURE 13
THE SAPIENT AND SZILARDIAN DOMAINS OF HUMAN EVOLUTION

for future human evolution which may be summarized as follows:

1. Traditional Encapsulation

This is the case where world population becomes fixed near the upper optimum of about nine billion. There will be no need for conceptual space to increase. Preservation of the past conceptual space and all its informational denizens will assure that each person develops only that conceptual target diameter, that individual conceptual mass, which will permit him to fulfill one of the available static roles. Little occasion will arise for any individual to deviate from the exact pattern harmonizing with a traditional niche he entered early in life. Few will ever encounter challenge or crisis. Man will have achieved the bliss of lungfish. (My verbalized spoonerism at this point was the "blish" of lungfish.) Like these inhabitants of Lake Manyara in Tanzania, we would have discovered how to encapsulate ourselves in a conceptual mudball, avoiding all opportunities and challenges. By this option we would reenter a traditional tribal way of life resembling that at the beginning of the human experience, with the exception that a single tribe would circle the globe.

2. Maximizing Biomass

The whole prior historical record of human progression reveals man's ability to free himself from the stricture of a carrying capacity for his biomass. Now that he is encountering another stricture, that of maintaining ideomass constant, he can still retain his freedom for some time to come from the stricture of maintaining a constant biomass. At least this can be done if there is a slowing down of population growth sufficient to harmonize it with utilizing the developing technologies of food production. With ideomass remaining constant, that is $I = Nd''$, it is apparent that if N increases, d'' must decrease. The conceptual target diameter of the average individual will decrease as population increases. Most individuals through successive generations will progressively be less aware of less and less. I prefer not to be involved in life dictated by either this or the first option. However, once either of these two routes had been followed for several generations, no one would suffer from not having considered the third option. The trajectory of survival would have long since erased the possibility of considering its existence.

3. Maximizing Conceptual Target Diameter

This option is that of enhancing the scope of human potentiality. For this to continue after ideomass remains constant means that as conceptual space, and therefore conceptual diameter, continues to increase, population must likewise continue to decrease. However, there will be a price exacted if this option is selected.

The course of human history has been one of placing increasing emphasis on individual development, despite the necessary focus on the integrity of enlarging groups. We, therefore, need to examine the path of this option and the price it will exact.

The left-hand side of Figure 13 duplicates Figure 11 except that, beginning at about the present, a decrease in population growth will permit avoiding the doomsday effect. Then natality will balance mortality. Included in this portion of the Figure are the conceptual revolutions, indicated by circled dots, as described above. Another, and the initial revolution, which was not discussed above is represented by the attainment (about 160,922 B.C.) of a stage of development of Homo erectus at which there began a very gradual recruitment of conceptual space. This culminated in the transformation of this species into Homo sapiens. Ordinate scales for conceptual space, A", and conceptual target diameter, d", are so constructed that their changes in magnitude over time are also represented by the same left-hand curve as represents increase in population.

Provided that birth control becomes sufficiently effective, a decrease in population can set in which will permit the world population to decline from an overshoot level back to the optimum of nine billion. This number reflects that population at which further socio-political union can no longer contribute to the effectiveness of communication among its members or the increase in their conceptual space. It is appropriate to designate this time as "dawnsday", for it introduces the opportunity of entering a new domain of evolution. I can only guess the duration of this lag-time, L, between doomsday and dawnsday. I have arbitrarily assigned L = 373 years. For this degree of decline to be realized, there must be a period before dawnsday during which there is about one child produced per female.

As population begins to decrease, it will then be possible for conceptual space to again begin increasing and still maintain ideomass constant. The issue then arises as to the nature of the rate of increase in conceptual space, as well as the rate of decrease in population after dawnsday. Dawnsday is approximated as 2400 A.D. After dawnsday, conceptual space will increase in a reciprocal fashion with respect to time as it did before doomsday. This increase in conceptual space permits the population to decrease within 40 years after dawnsday to the same number as about 40 years before doomsday. That is to say, there will be the same population in 2440 A.D. as in 1988 A.D. It may be noted that both population and conceptual space doubled twice in the 120 years up to 1988 A.D. If conceptual space doubles twice in the 120 years after 2440 A.D., population must drop in half. During this 120 years, conceptual target diameter would have doubled and, thus Nd" would maintain ideomass, I, constant. As the population decreases, it will require

its members a longer time to create doublings of conceptual space. Every time conceptual target diameter doubles and population halves, we may anticipate a conceptual revolution of perspective and means of coping comparable to those which preceded doomsday. The time intervening between any two successive revolutions will be four times that between the first of these two and the one which preceded it. This is exactly the reciprocal pattern of the time sequence of conceptual revolutions before doomsday.

Continuation of this process would ultimately lead to a time when target diameter approaches infinity and population approaches zero. This is an unreal time, in the sense that it is many billions of years away. However, we need to examine the implications of d" increasing as N decreases. A reason for the electronic revolution is that we have approached a limit of the cortex to process information necessary for its codification into concepts. By the same token, we are in much more difficult straits with regard to the ability of the cortex to integrate and condense concepts to the point that they represent sufficiently significant units of creativity to enlarge conceptual space. This means that we will shortly need electronic prostheses which will function much as does our cortex. We become linked to these to permit further enlargement of our conceptual target diameters beyond the limitations imposed by the cortex.* Such coupling with thinking prostheses represents the character of the evolutionary progression after dawnsday. All further increases in conceptual target diameter after dawnsday will result from elaboration of thinking prostheses to which we may link. Maintaining these linkages is the price we will pay if we elect the third option of further enhancing human potentialities as the desired course of evolution. If the projected process of decrease in population and increase in conceptual target diameter continues for as long after dawnsday as the human experiment continued from the Homo erectus revolution to doomsday, then more than 99% of the conceptual target diameter of the average individual will result from activity within thinking prostheses to which he is linked. This time, which is about 165,340 A.D., I will designate as Szilard time, t_z, in memory of

* Our laboratory has been working for some time on the development of a model of the relationship between generic concepts, which if further substantiated would have some bearing on the design of thinking prostheses. By "generic concept" we mean broad concepts such as indicated by such words as change, misery, design, health, or adaptation. Where every such concept is represented by a ball and equal-length rods (representing linking concept descriptors) connect balls; then a network is formed in which the balls connected to any particular ball form the corners of a icosahedron. The centermost concept is apparently either "design" or insight" and the opposite poles of one major axis through the center are the concepts "balance" and "loss".

Leo Szilard who visualized its arrival. Szilard in his short story. "Calling All Stars", projects to a time on a planet he calls "Cybernetica", when the population of thinking organisms had already gone to zero and all that remained was 100 minds, 100 thinking prostheses, then subservient to beings living on the North Star [35, p.122]. I find it difficult to believe that Szilard was just spinning a yarn, but rather that from the depths of his insights into nuclear physics, coupled with his deep concern for human survival, there was a premonition of the possibility of the course of the third option I have been outlining.

For this reason, I wish to designate the domain of evolution from dawnsday to t_z as the "Szilardian Domain of Evolution". At its inception it will no longer be appropriate to designate man as Homo sapiens. He, rather, must be given a specific name reflecting the developing linkage with thinking prostheses. At that time it may be appropriate to designate man as Homo leo for a dual reason. This specific name reflects Leo Szilard's vision. It also reflects the propensity of man to develop commensal relationships. I have in mind here a commensal bond between earlier forms of man and the lion, Felis leo, which permitted them both to evolve. This hypothesis of mine of this earlier commensal relationship must remain in its present form as a mere assertion until I have completed further documentation.

CONCLUDING REMARKS

One normally thinks of space in one of two general ways. During the past few years the attention given to launching man into explorations of interplanetary space has focused so much on this view of space that we have tended to ignore ways of viewing space here on earth. Perhaps the present efforts to explore extra-terrestrial space will have a bearing on the inception of a domain of evolution involving communication between planets which will follow the Szilardian domain of evolution. With regard to space on earth, we view it from its dimensional properties, from its structural content, and from the activities which take place within it.

My whole career has been dominated by a concern with physical space as it relates to the welfare of members of contained individuals and the growth of populations. In 1955 Leonard J. Duhl and I organized a committee for considering "The Influence of Physical Environmental Variables on Mental Health".* Under Duhl's leader-

* Beside the organizers, the initial members who remained as core participants throughout the several years of meetings were: Catherine Bauer and/or Melvin Weber (city planning), Edward S. Deevey, Jr. (ecologist), A.B. Hollingshead (sociologist), Erich Lindemann (preventive psychiatry), Richard Meier (social planner, chemist), Richard Poston (community planner, journalist), Nicholas Rashevsky (mathe-

ship, this group continued to meet for two three-day sessions each year for 12 years. After two years, the designation of the group was changed to a committee to consider "Physical and Social Environmental Variables as Determinants of Mental Health". Because of the cumbersomeness of this designation, we soon acquired the appellation, "The Space Cadets", in recognition of the interdependence of social processes to the properties of the physical space within which they transpire. My association with the many leading minds which flowed through this committee strongly influenced my continuing search for the meaning of space for the life and survival of man. Were it not for this association with this wide scope of ideas in ferment, I would have been unable to follow the relationship between physical and conceptual space and envision the impact that the emerging electronic and compassionate revolutions will have on society.

Every conceptual revolution brings with it new demands on communication, including adaptation of old forms to new circumstances and development of new forms. The present time is particularly acute and unique in this connection. We are simultaneously involved in four revolutions, because of the extreme foreshortening of the time intervals between conceptual revolutions. This situation is aggravated by the fact that those parts of the world which were delayed in attaining earlier revolutions are now caught up in a process of telescoping a formerly slower change. This produces a nearly simultaneous embarking upon several revolutions. Even the nations at the forefront are still tying up the loose ends of the scientific-exploitive revolution while they are preparing to usher in the communication-electronic revolution. And, as is true with the emergence of all conceptual revolutions, a minority segment of the population is involved in grappling with the issues which will later dominate the scene. This concerned minority, now directing its attention toward the compassionate-systems revolution, is rapidly swelling its ranks. On it falls the additional burden of plotting the path through the transition of cessation of population increase into a new and challenging domain of evolution. No one can escape participation in these present times of crisis; literally everyone must become involved in developing the opportunities these crises present. A small collection of functions and attitudes stand out as meriting our attention:

1. The Alerting Function [11, p.7]

The just terminating scientific-exploitive revolution, in its focus on mining resources, has evolved extremely efficient administrative capacities for directing motor functions of institutions. Execution of administrative functions subsumes established goals. On the sensory side, institutions remain relatively blind. Few in-

matical biology), John Q. Stewart (astro-physicist, social physics), John R. Seeley (sociologist), Thomas Gladwin (anthropologist).

corporate adequate means for assembling and integrating knowledge relevant to how the actions of other institutions, or other subsystems, affect their own performance and how their own function has effects permeating beyond the restricted conception of their mission. In particular, most institutions lack accessibility to information prerequisite to the evaluation and reorientation of their missions. Fulfilling the alerting function requires that the institution devote as much effort to this sensory function as to the more customary administrative motor functions. It is imperative that these two functions be kept distinct, though tightly linked. They must be performed by different individuals and different groups.

2. The Appreciative Function*

Given that an adequate functioning of the alerting system makes all necessary information available, there still remains the problem of its utility in reevaluating former goals or in producing new directions for the institution. Effecting this function requires a special group of individuals who serve as a linkage between the appreciative system and the administrative system. Members of this linking group within the institution also have the responsibility for developing directions and formulating evaluations. These evaluations relate both to impacts on the institution from outside of it and to impacts generated within it. Final decisions based on this information, which will govern the later activities of the institution, remain as an integral responsibility and prerogative of the administrative function. The number and complexity of concepts, as well as the volume of simpler forms of information required to develop these evaluations and directions, place excessive demands on cortical function. There already exists a need for techniques and technologies which simulate brain function to meet the demands which should be placed on appreciative systems.

3. The Dialogue Function**

Dialogue is the muted confrontation among parties seeking fuller awareness of common problems, resolution of value conflict or agreement upon principles and theory. I am reminded of the wild stray tomcat that adopted our house as his home. For some months he would accept handouts only after we had retired from where they were left. Perhaps he also sensed that I had not held cats in particular high regard. At first my slightest touching him elicited a swatting scratch or an attempted bite. Now, a year later, when I tease or

* Original formulation of "appreciative system" by G. Vickers, [36], related treatment of development of new images by K.E. Boulding [3, p.199] and J.B. Calhoun [12, p.9].

** J.B. Calhoun proposed this in the introductory remarks to the symposium, "The Dialogue of Change: Systems in Interaction" [13, p.9]. Since this symposium was held, the public information media in particular have focused on the subject of dialogue with increasing frequency.

stroke him too vigorously, he slaps his paw with claws retracted against my hand, or holds on to my fingers with his teeth without breaking the skin. How well we have resolved our differences, I am not sure. I can only say that I now find it difficult to sit down in my favorite chair to read without a furry ball of fat landing in my lap.

Provocation of crises through violent confrontation may at times be necessary to precipitate a more meaningful exchange between individuals or institutions. Social tradition and lack of designed relations have sufficiently separated them that they no longer can communicate about common interests. The need is to develop the muted confrontation of dialogue as soon as possible. However, present values and institutional arrangements are inadequate to make dialogue effective. Without more effective dialogue, we will encounter extreme difficulty in arriving at the compassionate-systems revolution and passing through the transition to the next domain of evolution.

4. Commitment

Moving down into the more individual level of function, commitment to goals beyond ourselves brings us to the full implication of the superposition of conceptual space upon physical space. We need to develop more effective means of becoming committed to involvement in furthering the realization of values and goals contributing to survival of society and expansion of individual potentialities. Commitment requires a preceding identification with values and goals, an increase in personal conceptual space. Actions implementing commitment involve defense of conceptual space. They replace the primitive "territorial imperative", and imply effective involvement in dialogue to permit shifts in commitment harmonizing with the evolving design for the survival and evolution of man and nature.

5. Compassion

I have already remarked in some detail about the perspective of compassion. Simultaneous expression of compassion and commitment becomes somewhat difficult and conflicting. This arises from compassion representing a transformation of subordination and submission, which takes place in conjunction with territoriality and the social hierarchies of physical space. Decreased status in physical space leads to acceptance and acknowledgement of the rights of others. By implication, acquiring the capacity for compassion requires periodic attainment and acceptance of the role of the "suffering servant".*

* Isaiah 52:13 to 53:12. For the initial formulation of "the Compassionate Revolution" see J.B. Calhoun, "A Glance Into the Garden" [14].

6. Creativity

I have already commented on the apparent dependence of creativity on an oscillation between periods of withdrawal from social pressures and the stresses of life and periods of reinvolvement with reality. This of course presupposes prior acquisition of a sufficient variety of knowledge and behaviors from which some meaningful reassembly may arise. Through such reorganizations having value for society, enlargements of conceptual space emerge. Beyond this, creativity serves the dual function of being a sublimation or replacement for both aggression and the need to express biological generativity. Lorenz points out that the threat behavior of territorial defense in primates is accompanied by pilo-erection and rearing to full height with elbows outward and chin up [27, ch. 13]. This stance in turn is accompanied by a feeling of exhilaration, of a shiver running down the back and arms. This exhilaration becomes compounded into what Lorenz terms "militant enthusiasm", when many individuals simultaneously engage in action providing this satisfaction to the aggressive drive. By implication, the releasor for militant enthusiasm becomes any threat, any set of strange objects, altered circumstances, or a divergent set of values. Lorenz further notes that the presence of an opposing camp provides the most essential circumstance permitting satisfaction through release of militant enthusiasm. So we must identify an "opposing camp" toward which there may be a legitimate expression of militant enthusiasm. This camp is recognized as any conceptualization suspected of inadequately enhancing experience or survival. This experience of exhilaration during aggressive defense of territory is essentially identical with the eureka experience of exultation classically described as accompanying creative associations. Thus, militant enthusiasm can find expression in creative effort.

As already mentioned, Erikson holds that curtailment of procreation can arise only when the generative need can be fulfilled by either involvement in the generative function of transferring one's values to others, or by engagement in the highest level of generativity creating new values or insights [21]. These three functions of creativity give a high priority to increasing the number of persons capable of creative acts.

7. The Psychedelic Trap

Since man emerged, increases in population have often swept far ahead of increases in conceptual space. These were times of crowding when no unsettled physical space remained and the needed conceptual space remained to be discovered. Peoples of all times and all places discovered the means of "turning on" and turning inward to a seeming replacement for the needed conceptual space. From Caapi in Brazil, to Karavi in Bombay, to Catha in Kenya [5,30], similar "mind-expanding" drugs from plants have been discovered. Each in its own way

leads to a transient feeling of having conquered the deficit of conceptual space, with hardly ever any meaningful creative association as an accompaniment. I use the word "meaningful" here to imply "relevance for survival". Because of the nearness of Kenya to the original Eden of man, I would like to adapt the word "Catha" to represent the state of exhilaration resulting from the use of mind-expanding drugs. Spelling Catha as "katha" incorporates the sense of the Egyptian word "ka" for spirit. Thus, katha is the exhilaration of the transient impression of having enlarged conceptual space. In contrast, eureka, though a transient exhilaration also, accompanies the creative act of contributing a unit of conceptual space to the evolving needs of man. Knowing katha is as easy as swallowing a cube of sugar. Knowing eureka often requires a difficult, frustrating, lonely, and usually time-consuming journey. Which route one selects depends upon how concerned one is for man's future.

PROMOTION [16]

Once man mastered the problem of sheer physical survival, he turned his attention to developing therapies for correcting the ills which beset his body, mind and society. Focus on correction led to awareness of the origins of pathology. This enlargement of conceptual space resulted in new roles devoted to prevention. Implementation of this new perspective reduced the effort devoted to therapy. Preventive activities extended to elimination or reduction of circumstances producing environmental pollution. The concept of conservation arose as a companion to prevention. It included corrective actions to recuperate from pathologies induced by the encroachment of technological society on nature. Conservation also amounts to prevention in that actions stemming from this concept intervene to ward off additional encroachments.

The new roles and new concepts that are developing as we begin to enter the compassionate-systems revolution now permit institutionalization of an approach having more immediate positive consequences than either therapy or prevention. This approach may be called "promotion". Promotion involves a design of efforts to enhance the development of potentialities, as well as assuring a continuance of the opportunity for their expression. Concern here is for both individuals and institutions. For promotion to become effective, the alerting, appreciative, and dialogue functions must be highly developed. The goal of the compassionate-systems revolution is promotion. It includes active participation in guiding evolution, evolution of all other forms of life as well as that of man.

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