CALIFORNIA INSTITUTE OF TECHNOLOGY

Engineering and Science

APRIL 1970

BIOLOGICAL BASES OF HUMAN BEHAVIOR

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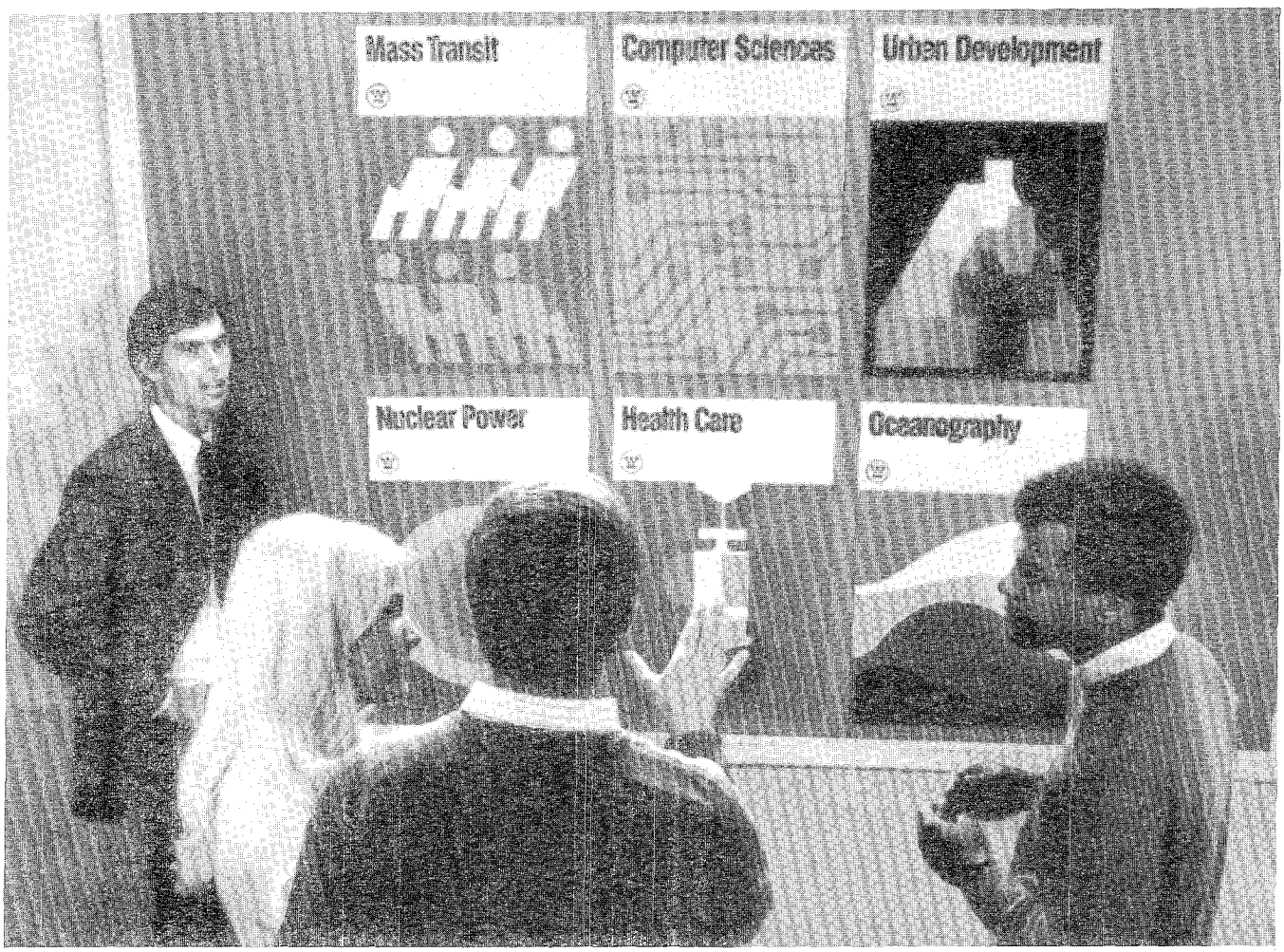

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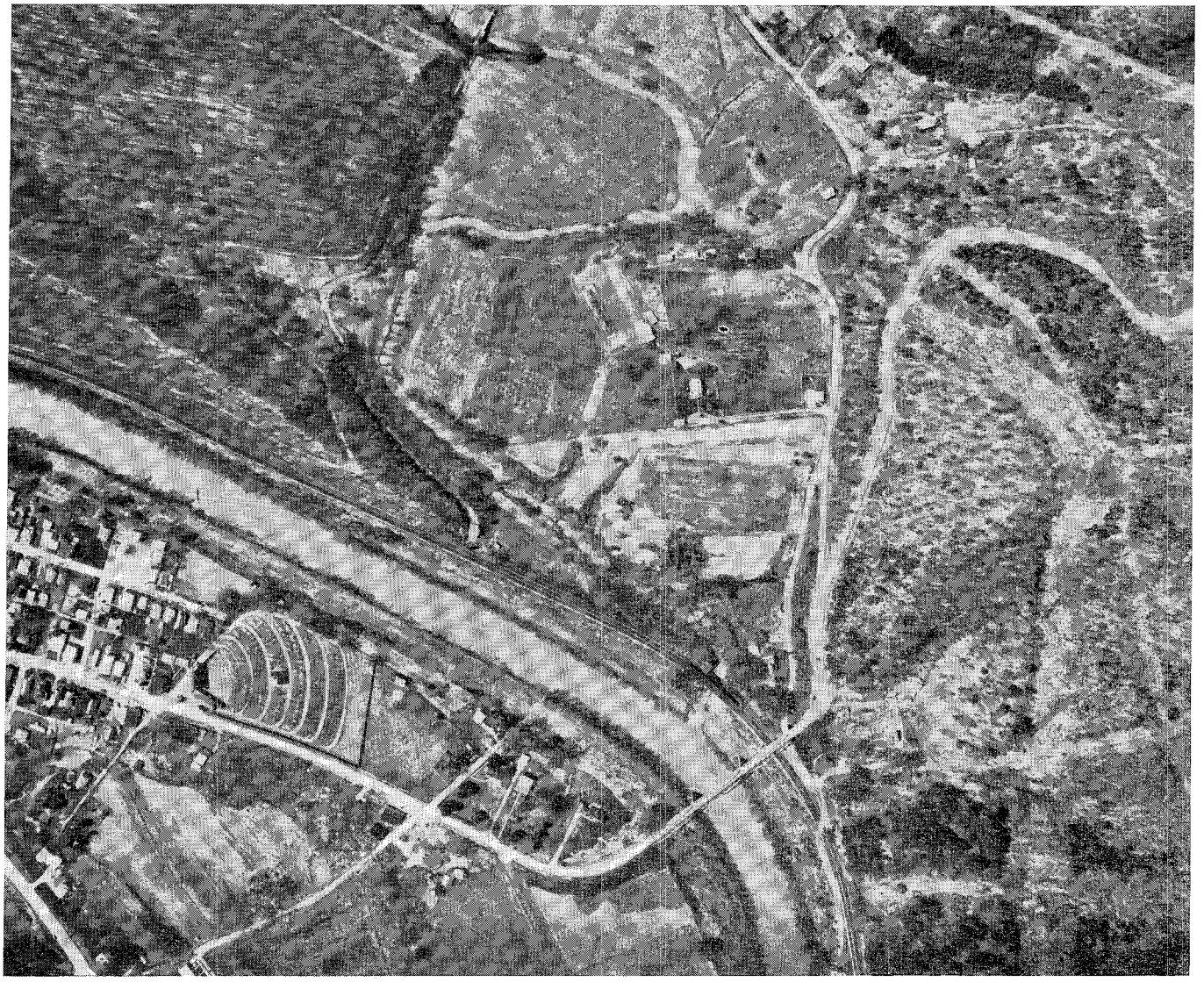

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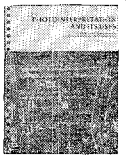

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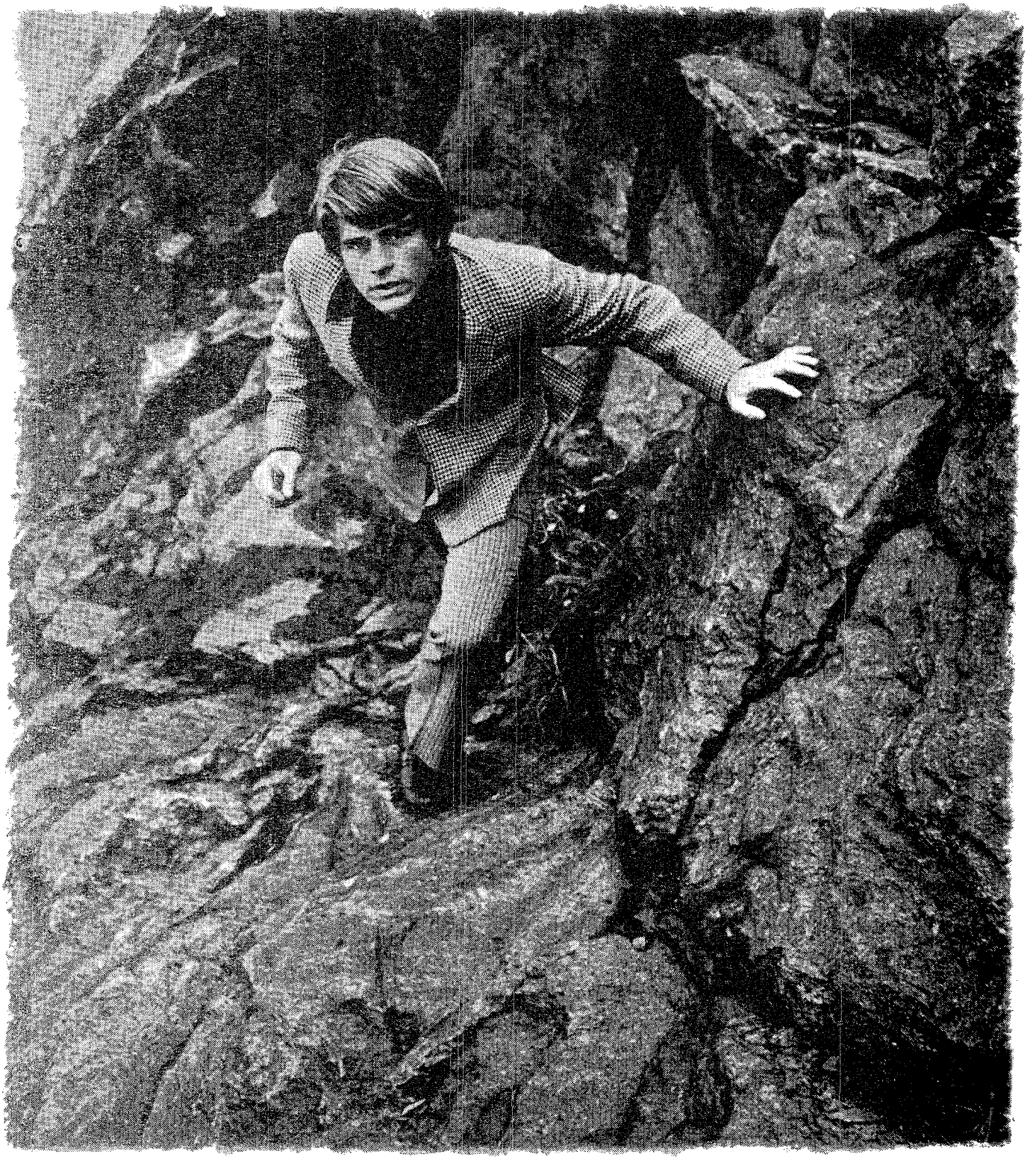

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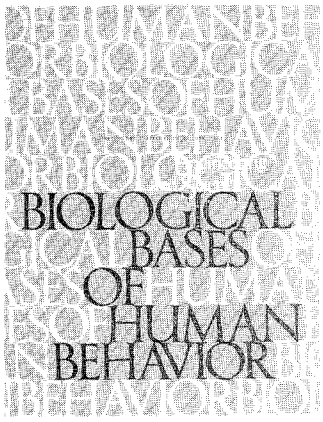

Engineering and Science

In this issue

This issue of *Engineering and Science* is devoted to a conference on the "Biological Bases of Human Behavior," held at Caltech March 16-18, 1970. Supported in part by a grant from the Alfred P. Sloan Foundation, it was the first of a series of four conferences to be held at the Institute in 1970 concerning scientific and technological advances of relevance to social problems.

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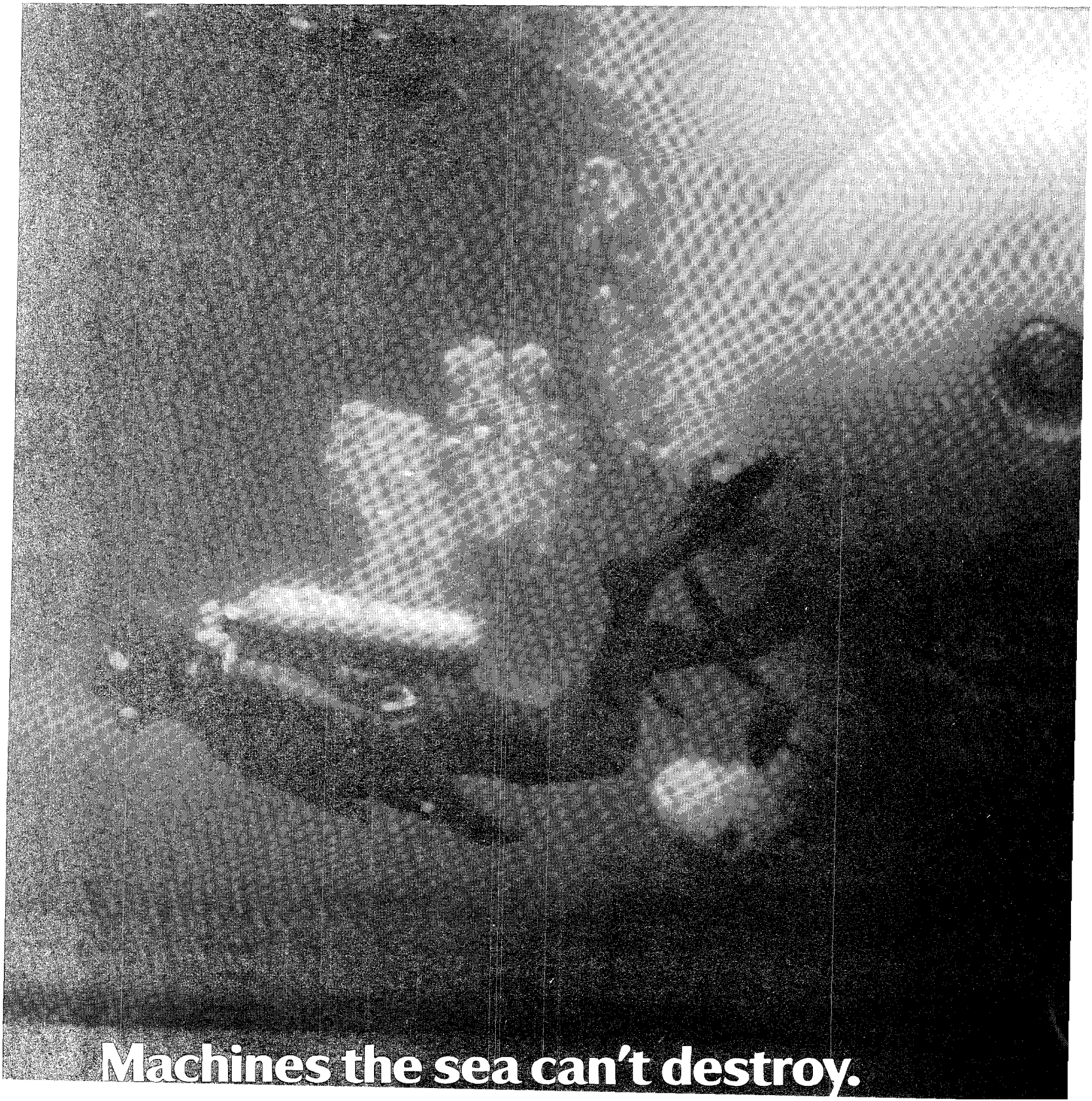

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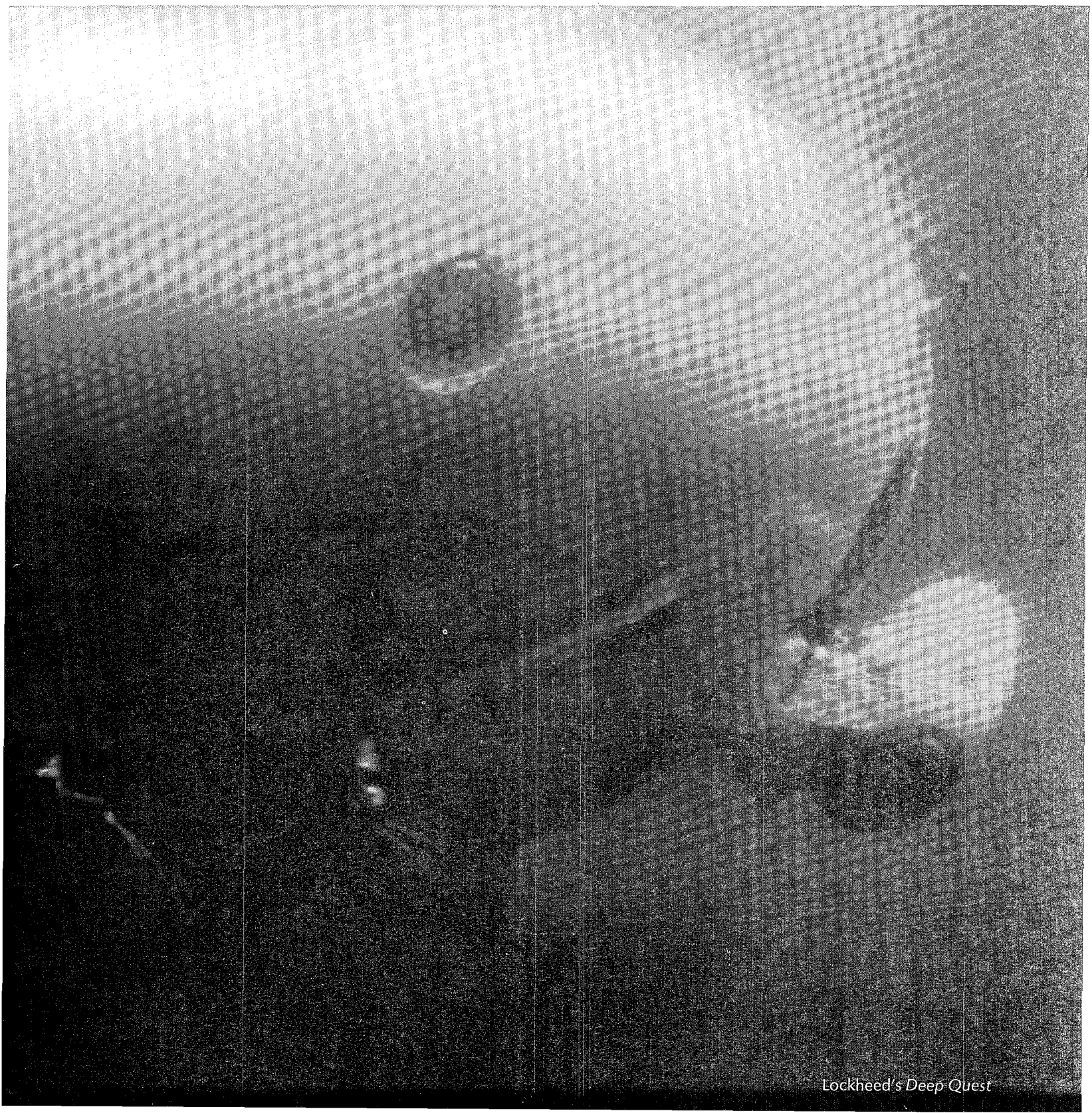


Engineering and Science

BIOLOGICAL BASES

A special issue of *Engineering and Science* devoted to representative selections from a conference on the "Biological Bases of Human Behavior," held at Caltech March 16-18, 1970.

Our concepts of the origins and the determinants, of the potentials and the far boundaries, of human behavior underlie the implicit assumptions that form our civilization and charter all of its institutions. Yet, only recently have the methods of experimental science been adapted to the examination of those assumptions—to the analysis of origins and the definition of boundaries—to the test and clarification of both issues long moot and tenets long unchallenged. Out of this effort, now embryonic and tentative, may come the bases for a more coherent and more satisfying social order, built upon a deeper understanding of the biological nature of man.

In different perspectives the biological nature of each human individual can be seen as a consequence in varied degree of his phylogeny, or his genetics, or his physiology, or his environment. In the conference at Caltech on the biological bases of human behavior we focused principally upon the first two of these determinants. Historically these have been the least accessible and hence the least understood; psychologically they are the least malleable, and hence the least socially palatable, and hence the most ignored. We are only beginning to comprehend their pervasive influence on the character of human perception and thought and the range of human variation.

Biochemical evidence at the deepest level of DNA structure now supports and quantitates the phylogenetic relationship of man to varied primate species. Recent studies, in the field and in the laboratory, of our closest biological relations have revealed that they too are past that evolutionary Rubicon at which the choice was made in favor of transmitted knowledge (by observation of experience and by imitative trial) over rigid inherited instinct—the prerequisite to civilization. The multitude of forms such civilizations can take, the variety of their styles and emphases (as illustrated in the panoply of cultures of New Guinea and Melanesia) demonstrate the range of possible balanced solutions to the human imperatives and

OF HUMAN BEHAVIOR

An Introduction by
Robert L. Sinsheimer

also the influence of the chance event or the rare individual upon the development of prehistoric societies.

Concealed behind curtains of seemingly universal custom lie unexpected and profound patterns of transmitted knowledge. The deep psychological consequences of motherless rearing of primates surely have major relevance to the subtle consequences of varied modes of human child rearing; likewise the persistent consequences of early environment upon the abilities of primates to perceive and adapt to later situations bear strong pertinence to the ways in which human children learn to perceive and formulate their universe.

The evidence for the major role of genetic factors in the determination of intellectual and psychic human characteristics continues to mount despite considerable antagonism, both objective and subjective. The conference heard of a recently discovered syndrome, leading to severe psychic disturbance, attributable to a clearly defined, inherited enzymatic defect in a somewhat obscure metabolic pathway. It learned of the profound consequences, in opposed directions, of an abnormal chromosome constitution upon the capacities of the affected individuals for verbal performance and for perceptual and motor performance. The impressive body of data leading to the conclusion that inherited factors play a dominant role in the determination of individual performance on IQ tests was critically examined. It is an important secondary consequence of this conclusion that, by accepted evolutionary theory, the existence of such a large genetic component for IQ variance can only mean that there has been relatively little selection in human history for those factors that govern IQ performance.

Sufficient valid data are now available to demonstrate that individuals with a certain abnormal chromosomal complement are significantly more likely to be unable to adopt socially acceptable roles than are persons with a normal chromosome complement. The implications of such findings, and their likely extension to yet undetermined genetic combinations, for the concepts underlying our judicial system are major and as yet only dimly realized.

While the statistical indicators of genetic determination provide most convincing tables of evidence, we are as yet profoundly ignorant of the biochemistry and physiology which must accompany the abnormal or pathological psychic states. Early research forays into this field are promising, but they are as yet primarily exploratory.

The subject matter of this conference touched deeply held beliefs; that it could be held calmly at Caltech is a tribute to the maturity of our community. Behind the technical language and the scholarly objectivity one could often sense the unstated yet implicit questioning challenge to long-established, unquestioned dogmas, and one could glimpse the origins of new and disturbing concepts, with factual base and wide frame of reference.

The conference has enriched and encouraged those at Caltech and elsewhere who will seek to comprehend the true nature of man.

Induced Psychopathology in Monkeys

by Harry F. Harlow and Stephen J. Soumi

We are trying to produce psychopathological syndromes as analogous to human disorders as possible. From that base may come techniques for rehabilitation of depression.

Some 10 years ago the staff at the University of Wisconsin Primate Laboratories initiated a research program designed to induce psychopathology in infant monkeys by means of abusive surrogate mothers. The program was far from successful, and we thought we had failed completely to produce psychiatric syndromes in these specific monkey infants. Then John Bowlby, a British psychiatrist, visited us, listened to our sorrows, and toured the laboratory. After he had observed our monkeys individually housed in bare wire cages, he asked, "Why are you trying to produce psychopathology in monkeys? You already have more psychopathological monkeys in the laboratory than have ever been seen on the face of the earth."

We call the housing situation where Bowlby observed abnormal monkeys "partial social isolation." Here monkeys live alone in wire cages where they can see and hear other monkeys, but cannot physically interact with them. Our monkeys had lived in this situation since a few hours after birth, and their personal-social behavior had progressively deteriorated. Because of this confinement the monkeys had been deprived of a mother's love. Perhaps of even more importance, they had never associated with agemates or peers, and therefore they had never had the opportunity for development of agemate love through play. Actually, mother love and agemate love are not competitive entities. Each has its own role, a complex interactive role, in the normal sequence of affectional development. However, when both types of love are absent, the monkeys' personal-social-sexual lives are destroyed.

When our monkeys were maintained in partial social isolation for several years, some of them developed what we call the catatonic stare: They stood in front of the cage looking vacantly into open space, paying no attention to other monkeys or people. Often the head of such an animal would turn to the left, the right arm would gradually be raised as if it had nothing to do with the body, and the wrist and fingers would go into a tight fist. When the monkey looked at the elevated arm, he would jump. He would be scared to death of this awesome appendage which he did not recognize as a part of himself.

Another interesting result of partial social isolation was that after a period of time aggression progressively developed. Aggression is a late-maturing development in human as well as nonhuman primates. The only reason that all of us are not sadistic monsters is that the maturation of love probably, for all animals, is antecedent to the maturation of aggression. Where there is antecedent mother love and agemate love, there is an amelioration of aggression toward social group members. However, aggression does mature, and when outside aggressional release was blocked in our partial isolates, these monkeys turned against themselves. This self-aggression is akin to Menninger's man-against-himself or Freud's death instinct. Self-aggressing monkeys do not ordinarily rip and rend their bodies apart, but under unusual stress some of these monkeys would rip their own arms and legs down to the bone.

There is a technique to raise nearly normal monkeys in partial social isolation—by providing them with a cloth "mother" monkey. In our original study on the surrogate mothers we saw and were not surprised that the babies would cling 23 hours a day to these cloth mothers. The behavior that did surprise us was that these inanimate cloth mothers imparted to the infant a sense of security,

When a monkey is reared in partial social isolation, self-destructive behavior may be his only way to express aggression. This monkey is actually ripping his own body—not ordinary behavior, but possible under conditions of unusual stress.

probably homologous to psychoanalyst Eric Erickson's first developmental stage—the stage of security—in the human child, which we feel is the mother's primary contribution to the infant's social-sexual development. It is maternal security that enables the infant to leave the mother and explore the inanimate world about him and, of even more importance, the animate world of playmates. This is why mother love is indispensable. It is an essential antecedent condition for the development of the totally important agemate or peer affection. Incidentally, there is little difference, aside from cultural and cortical factors, between human children and monkey children—except age. Monkeys grow up four or five times faster than human children by a wealth of different criteria.

Knowing that a mother could give an infant love and security, we thought many years ago that we could produce anaclitic (dependency) depression by allowing baby monkeys to attach to cloth surrogate mothers who could become monsters. It was a fascinating idea, but as we have already conceded, the methods were less than totally successful.

The first of these monsters was a cloth monkey mother who, upon schedule or demand, would eject high-pressure compressed air. It would blow the animal's skin practically off its body. What did the baby monkey do? It simply clung tighter and tighter to the mother, because a frightened infant clings to its mother at all costs. We did not achieve any psychopathology.

However, we did not give up. We built another surrogate monster mother that would rock so violently that the baby's head and teeth would rattle. All the baby did was cling tighter and tighter to the surrogate. The third monster we built had an embedded wire frame within its body which would spring forward and eject the infant from its ventral surface. The infant would subsequently pick itself off the floor, wait for the frame to return into the cloth body, and then again cling to the surrogate. Finally we built our porcupine mother. On command, this mother would eject sharp brass spikes over all of the ventral surface of its body. Although the infants were distressed by these pointed rebuffs, they simply waited until the spikes receded and then returned and clung to the mother.

These infant monkeys' behaviors were not surprising. The only recourse of an injured or rebuked child—monkey or human—is to make intimate contact with the mother at any cost.

We then measured the effects of total social isolation, where from a few hours after birth for as long as the experimenter desired the monkeys saw no animal of any kind. When monkeys that were totally socially isolated for 3 months were put with other infants, one or two of them died of emotional shock, self-induced anorexia (loss of appetite). But if they survived the shock—and they all survived when we understood the problem—these animals became normal within a period of a couple of weeks or a month at most. They played effectively with other normal 90-day-old animals and showed absolutely no intellectual deficit.

However, 6 months of total social isolation is very different from 3 months. Three months is like putting a human child in an inadequate orphanage for a year—and all orphanages are inadequate. Six months for a monkey is like 2 years of orphanage isolation for a human child.

The prognosis for a human child living in an orphanage confinement less than 1 year is favorable. After 2 years of orphanage confinement the prognosis for a human child is not hopeless, but it is unfavorable. Our 6-month isolates showed very little contact play, which is an effective social

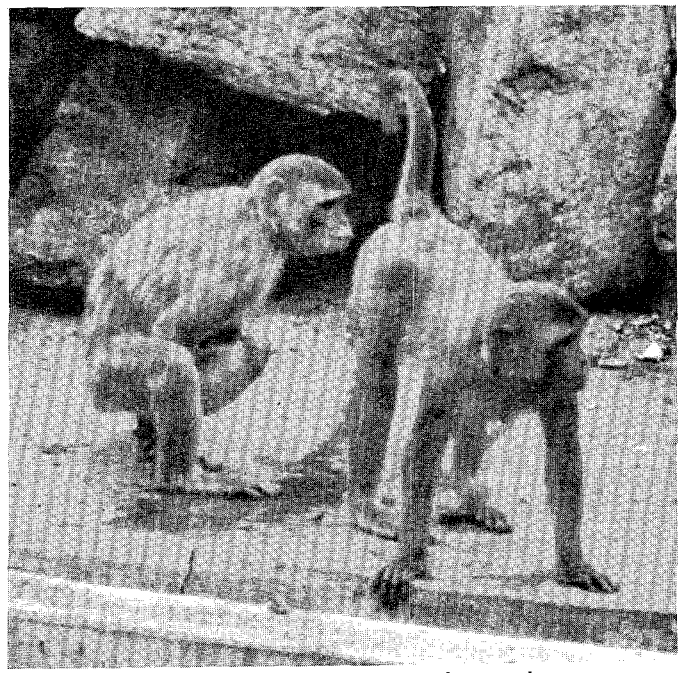
The babies that survived rehabilitated their mothers, because by attaching themselves to the breast and the ventral surface, they eventually elicited maternal affection.

measure, when placed with normally raised monkeys of the same age. Actually, over a long period of time, the 6-month isolates made slight recovery. They showed some social behavior with other 6-month isolates, but not with normal agemates.

Activity play is a very simple measure of social adjustment for rhesus monkeys. Even this pattern does not exist in the 1-year monkey isolate, a condition homologous to that of a human child raised in a very inadequate orphanage for 4 years. In the experiment involving 12 months of social isolation our standard technique of placing isolate monkeys with equal-aged normal agemates had to be terminated after 10 weeks, because by this time the normal 1-year animals were virtually tearing these isolates to ribbons. Aggression had developed in the normal monkey, and the 1-year isolates were totally defenseless. It is a standard psychological rule that dead animals do not make adequate subjects for social research.

Furthermore, the effects of social isolation for 6 months or more (we also have data on 9, 12, and 18 months) appear to be permanent. Six months of total social isolation forever devastated these monkeys socially.

Another activity destroyed by total social isolation was normal adult heterosexual behavior. When we first separated monkeys from their mothers, we wanted to build a great colony of disease-free breeding stock. There was just one flaw in our plan: There wasn't any breeding. In desperation we tried our first group-psychotherapy program, which utterly failed. We took 15 of the oldest males and 15 of the oldest females who had been separated from their mothers at birth and put them on an island in the Madison Zoo. We had the pious hope that on some enchanted summer evening the full moon would rise over the waters of the neighboring lake, the wind would waft its fingers through the leaves of the trees, and something other than just seeing eye to eye would take place. At the end of the summer we had seen no example of normal adult heterosexuality, only ill-directed and infantile efforts.



Monkeys raised in total social isolation are destroyed for normal heterosexual behavior. Here in a zoo, where an attempt was made to breed such animals after they grew to adults, they could make only ill-directed and infantile efforts at copulation.

We wanted to test the effect of social isolation on maternal behavior, but no one can study maternal behavior unless someone has babies. Actually, for about 50 percent of our isolated females we eventually found ways to breed them under controlled conditions. The technique we devised in desperation was a rape rack.

When motherless monkeys that had been raised in total isolation for 6 to 9 months became mothers, at least two-thirds of them turned out to be inadequate or evil mothers. They tended to show one of two syndromes. One pattern of the motherless mothers was to pay no attention to their infants. (Any normal monkey mother hearing one cry from its baby would have clasped the baby to its breast in no time flat.) The other mothers were brutal or lethal. One of their favorite tricks was to crush the infant's skull with their teeth. But their really sickening behavior pattern was that of smashing the infant's face to the floor, then rubbing it back and forth.

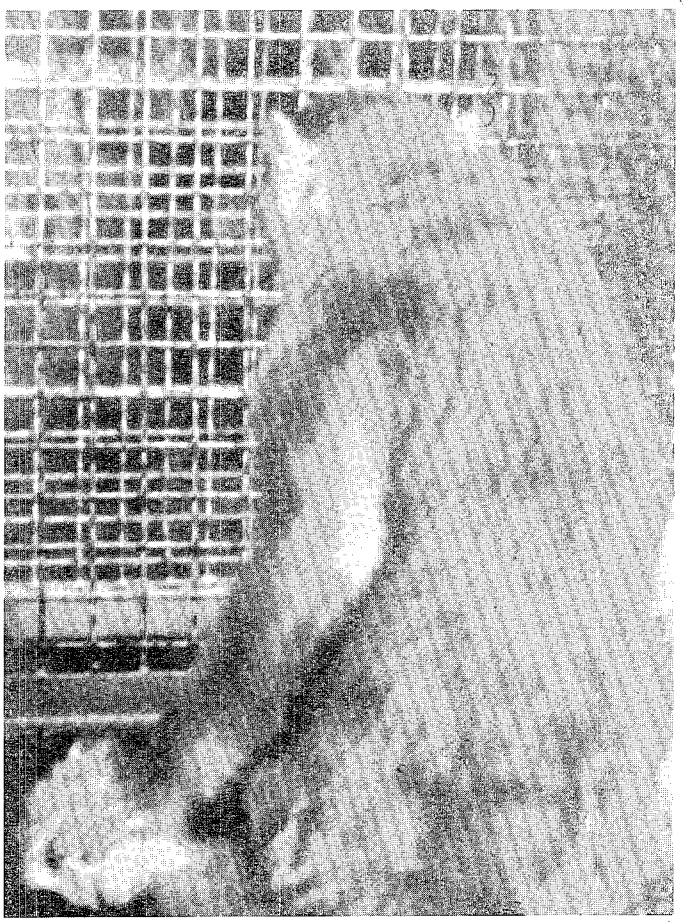
Now the interesting thing from a psychotherapeutic point of view was that the baby monkeys raised by these monster mothers (we had given up on the artificial monster mothers because we couldn't produce any as evil as a real monster mother) never gave up unless they were killed. The babies went back and back and back to their mothers, trying forever to attach to the mothers' back and then worm around to the ventral surface and breast. We kept the infants that survived with their mothers for 6 months. By the fourth to sixth month the babies were making as frequent—we won't say as long—contact with the monster

mothers as were the babies with the good mothers. In a manner of speaking, the infants had healed the mothers. And these mothers, who eventually became maternalized by their first babies, were, on the second, third, or fourth pregnancies, for all practical purposes, perfectly normal mothers. The babies had rehabilitated the mothers, because, by attaching themselves to the breast and the ventral surface, they eventually elicited maternal affection.

These studies convinced us that production and study of psychopathological behavior in monkey subjects was feasible, despite the failure of our earlier efforts. Subsequently we have embarked on a serious program to produce psychopathological syndromes as analogous to human disorders as possible. The specific human disorder we are attempting to simulate is depression. There exists a considerable body of research on depressive effects of monkey mother-infant separation stemming from both our own efforts and those of other laboratories. The depressive syndrome produced in infant monkeys is similar to human childhood or anaclitic depression resulting from maternal separation as described by the Swiss psychologist Rene Spitz and by Bowlby.

In our first two studies of mother-infant separation in monkeys, we put eight infants who had been separated from their mothers in play areas. The baby monkeys exhibited Bowlby's first two stages of separation—protest (locomotion and vocalization) and then despair (self-clasp, rocking, and huddling). The most striking illustration of the despair stage was near-total abolition of all play behavior. All studies of primate mother-infant separation have obtained these same results.

Suomi measured the effect of multiple repetitive separations of infants from other infants instead of single separations of infants from mothers. The technique gave elegant results and with relatively minor individual differences. During each of the 20 separations, the infants showed a period of protest, followed by a period of despair. Each time they were reunited, recovery rapidly ensued. However, a phenomenon that no one could have predicted was that these multiple separations drastically changed the infants' development—it infantalized the behavioral growth process. We collected normative data over the period of the first 9 months in normal monkeys, and normal infants do not behave the same way at 9 months as they do at 3 months. Normal infants are only beginning to play at 3 months and display much clinging and self-orality. But by 9 months clinging and self-orality have virtually disappeared, and play dominates their social activities. For the infants suffering from the effects of multiple separations, ventral clinging to another monkey and compulsive self-orality, which are very infantile responses, were as high or higher in the last 3 months as in the first 3 months. Play should have been higher than



Smashing her infant's face to the floor, this monkey displays a sadistic maternal behavior pattern characteristic of motherless monkeys raised in social isolation. Other "monster mothers" may be totally indifferent to their offspring.

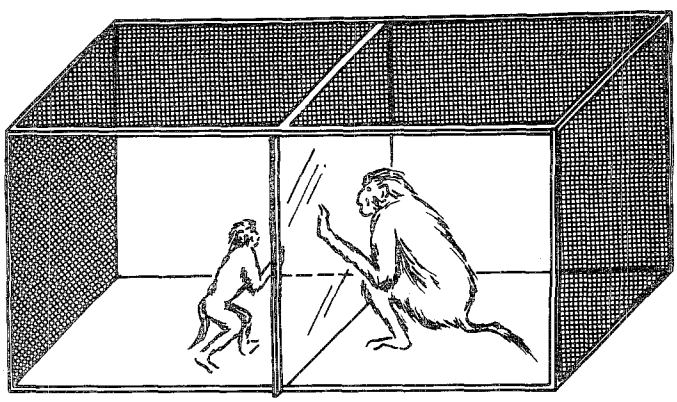
We put the isolates in pairs with normal, younger "therapist" monkeys; after 6 weeks it was hard to distinguish between them, because the isolates were exhibiting normal behavior.

cling or self-mouth at 9 months, but the converse was true, even though the subjects were in a situation where they had every opportunity to play. This experiment achieved effects similar to running a flatiron over the maturational process.

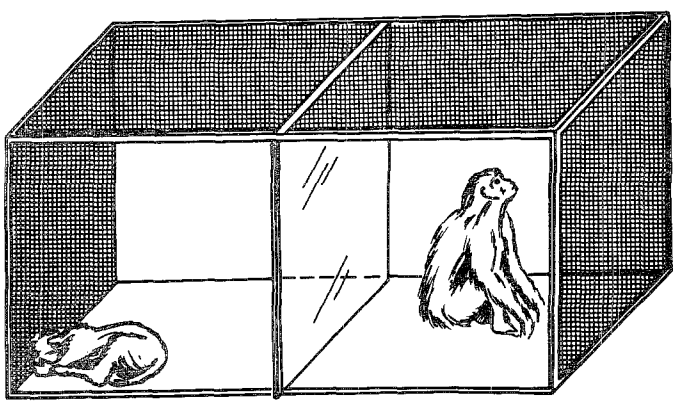
Buoyed by these results, we have continued to search for techniques to produce depression. Our criteria for operationally defining depression are primarily behavioral. We want to produce subjects who, prior to manipulations, show essentially normal behavior and, following manipulations, display very low levels of motor, exploratory, and play behaviors, very high levels of passivity, and possibly decreased food and water intake. One reason for producing such a syndrome is that one cannot do effective research on any antidepressant agent until a behavioral syndrome has been achieved that is descriptively unequivocal and reliable and can be maintained for weeks and months on end.

Obviously, one cannot combine physical and psychological disturbance and draw proper conclusions concerning depression. Accordingly, we have designed a device for producing depressive behavior without imposing physical discomfort on the animal. This device is called a vertical chamber or pit. Confinement in the vertical chamber produces an extremely depressed monkey, and one that remains depressed for many months following removal.

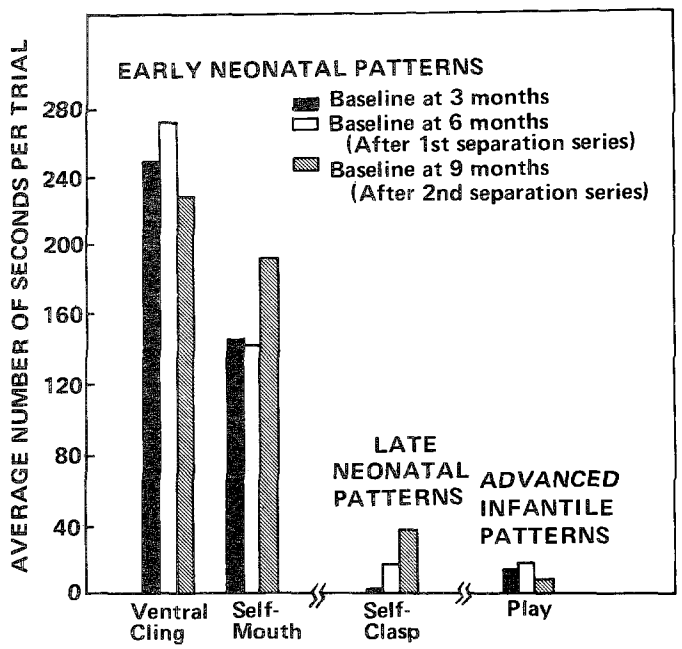
The animals in this vertical chamber can move about freely in all three dimensions, but they gradually cease to move at all. After a day or two, or for some a week or two, the monkeys assume a crouched posture akin to depression: It is a "giving up" posture. This kind of response in monkeys looks like human-type depression.



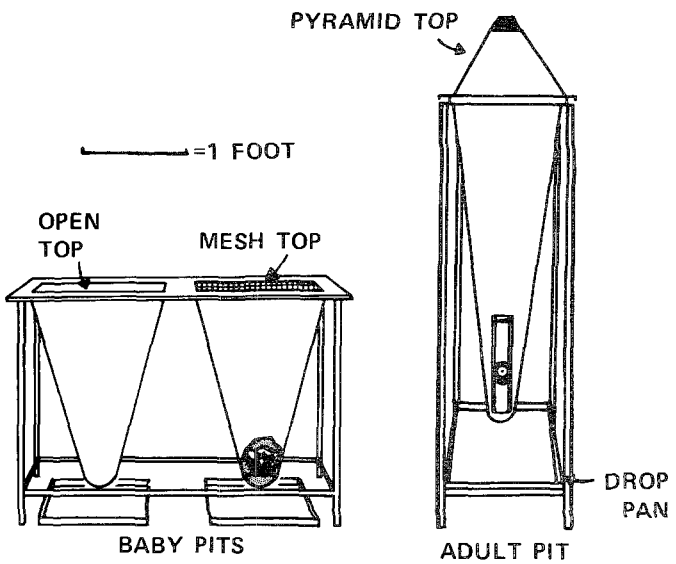
PROTEST STAGE OF SEPARATION



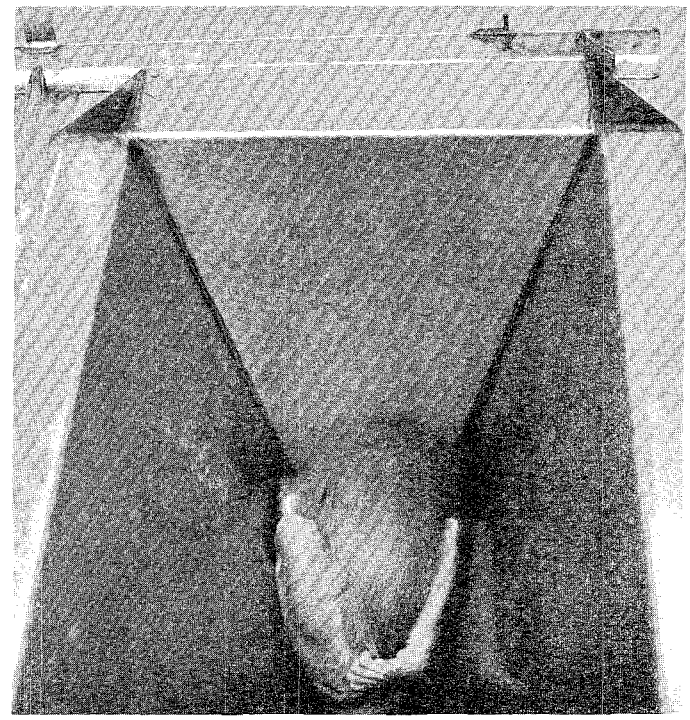
DESPAIR STAGE OF SEPARATION



Infant monkeys separated from their mothers (left) first protest, then despair. The separations, repeated over a period of time, effectively wipe out the more advanced behavior that the infants would develop under normal conditions (above).



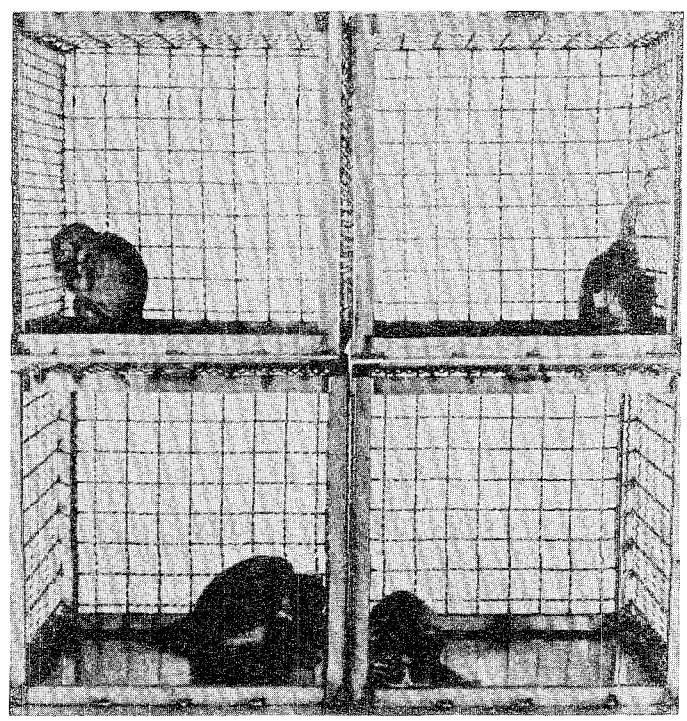
The vertical chamber, in which monkeys can move freely without restraints, produces depressed behavior without making the animals physically uncomfortable.



After a few days—or perhaps a week or two—the monkey in the vertical chamber stops moving about and assumes a "giving up" posture (above). Even long after removal from the chambers, young monkeys (below) show depressed and infantile behavior.

Following removal from the chamber, these responses persist. Infantile behavior increases enormously after vertical-chamber housing, and the ability to perform the more complex social tasks is simply wiped out. Vertical-chamber confinement produces effects homologous to human infant anaclitic depression.

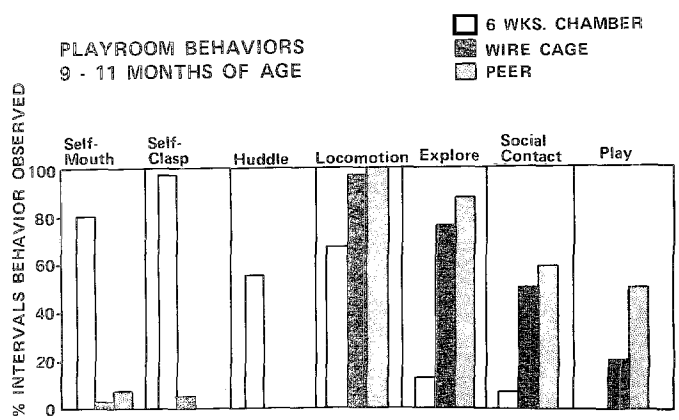
We are now comparing animals raised under three different conditions. One group had 6 weeks of isolation in the vertical chamber; one was raised in a wire cage from birth; and the members of the third group were raised as together-together animals—infants put together without any mother, real or artificial. Simple infantile response patterns remain very high for months in those monkeys chambered for only 6 weeks. More complicated social behaviors were simply eradicated in these animals long after chamber release.



While the immediate goal of our present research is to produce reliable, generalized, stable, long-lasting syndromes of behavior analogous to those exhibited by human patients diagnosed as depressed, it represents only a first stage of our over-all depression project. The next step is to modify existing procedures so that the *degree* of depression subsequently exhibited by the monkeys can be controlled. When this is accomplished, it will open up vast possibilities for parametric study of factors antecedent to depression-inducing manipulations which should either facilitate or hinder production of the syndrome. For instance, it would be possible to determine if monkeys with limited social experience are more susceptible to such manipulations than monkeys given unlimited social interaction throughout their lives, or

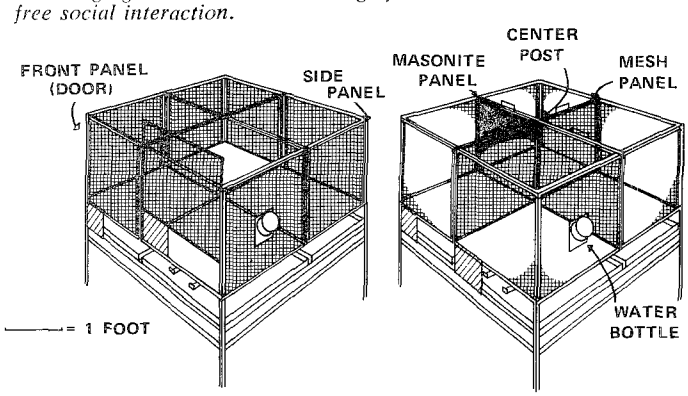
whether early exposure to stress-inducing situations inhibits or exaggerates the effect of the depression-promoting manipulations. Such information could conceivably provide valuable insight and aid in the understanding of factors predisposing to human depression. The primary current source of such information concerning human beings is retrospective analysis, a useful method in formulating hypotheses but of limited value in experimental control and manipulation of key variables.

To accomplish these aims we are using a combined living-experimental cage, named the quad cage, designed by Suomi, where four animals can live in separate chambers. These animals can be separated within the quad cage by wire, Plexiglas, or movable opaque slides, or allowed to interact freely. Social interaction behavior in the home cage is the simplest behavior in the simplest test situation that can be studied. The home cage also provides the environment in which deprived monkeys best show recovery. In addition, we are using what we call the playroom as a test situation, which has been highly standardized for studying development of infant-infant affection and for studying recovery from social loss following various antecedent events.



This chart shows the responses at nearly one year for monkeys raised under three different abnormal conditions: total isolation (chamber); partial isolation (wire cage); and together with another infant but with no mother, real or artificial (peer).

This quad cage is designed for maximum flexibility in arranging test situations that range from isolation to free social interaction.



COMBINED LIVING EXPERIMENTAL CAGE

A final, and perhaps most important, aspect of our research program involves the development of techniques for rehabilitation of depressed subjects. Possible techniques include behavioral, physiological, or pharmaceutical manipulations, either alone or in combination. Some conceivably could be modeled from existing therapies for human patients, such as electroshock therapy or antidepressant drugs.

We are also employing our own technique of "group therapy." Remember that if you place infant monkeys raised in total isolation for 6 months with equal-aged normal monkeys, the isolates remain socially damaged. However, we have recently raised a group in total social isolation for 6 months, along with a follow-up group 3 months younger. This younger group has been carefully raised so that they would be socially normal, having had both surrogate mothers and playmates. When the isolates, who without special intervention would have been destroyed for life, were removed from their isolation chambers, we put them in pairs with the normal, younger "therapist" monkeys. After about 6 weeks it was very difficult to distinguish between isolates and therapists, because the isolates were exhibiting normal social behavior. It appears that this experiment, which is very close to completion, will disclose highly significant effects of rehabilitation for these 6-month isolates.

It is essential to realize that the findings of such work hold implications for human depression only at the level of analogy and within the limitations of comparative behavioral research. Nevertheless, we feel that our findings from investigations of depression in monkeys will be important to human therapists working in an area currently devoid of data from controlled research.

Recent Evidence on the Evolution of Aggressive Behavior

by David Hamburg

Whatever adaptive functions aggressive behavior may have served in man's past, there is serious question about its utility now.

Why study animals if we wish to understand man? We do this primarily to obtain an evolutionary perspective in which we hope to perceive how man came to be the way he is, and to search for subtle legacies of his ancient past that may be carried with him through both biological and social transmission. We deal mainly with broad trends in evolution—asking whether certain characteristics of vertebrate, mammalian, and primate organisms are maintained or may even become more prominent as we come closer to man. If we find certain characteristics that appear to be especially important in the adaptation of man's closest relatives, then we must look in man to see whether these characteristics are present in him, too, albeit in some complex and obscure way. Such a search also tends to highlight man's distinctive and even unique features, such as language.

Animal behavior may be investigated not only in the laboratory, but also in artificial colonies or in natural habitats. The kinds of information gleaned from each setting are complementary, and all are necessary if the complex roots of behavior are ever to be understood.

Despite recent interest in the subject, very few field studies of primate behavior have focused primarily on aggressiveness. For this reason Eric Hamburg and I undertook a brief field study of aggressive behavior in chimpanzees and baboons in East Africa. We were very fortunate in getting more than 200 hours of close-range observation. We also had generous access to the files of the unique chimpanzee study in Tanzania conducted by Jane Goodall since 1960. With help from her and from another experienced field worker, Phyllis Jay Dolhinow of Berkeley working in Kenya, we acquired a good deal of data on aggressive behavior in the two species.

By aggressive behavior, in this context, we mean threat and attack patterns. We try to describe such patterns, the conditions under which they are likely to occur, and the circumstances in which they are likely to be diminished or terminated, particularly by means of interanimal communication. We chose chimpanzees because they are man's closest living relatives. Their social behavior is as close to that of man as we can find in nature.

Goodall's study is already a classic. She has described a remarkable repertoire of closely linked, usually sequential classes of behavior—aggression, submission, reassurance —with a rich variety of patterns within each class. The similarity of many of these patterns to those of humans is more impressive than the similarity of such patterns in any other nonhuman primate species.

What are the conditions under which the threat and attack patterns occur in chimps? From Goodall's observations and our own, I would summarize them briefly this way.

1. Competition over food, especially that which is highly desirable, spatially concentrated, or in short supply.
2. Defense of an infant by its mother.
3. A contest over dominance prerogatives of two individuals of similar social rank.
4. Redirection of aggression—that is, downward in the hierarchy (such as when a low-ranking male, who has been attacked by a high-ranking male, turns to attack an individual in turn subordinate to him).
5. A failure of one animal to comply with a signal given by the aggressor.
6. Strange appearance of another chimp—for example, one whose lower extremities became paralyzed during a poliomyelitis outbreak.
7. Change in dominance status over a period of time, especially among males.
8. The formation of consort pairs at the peak of estrus. In the early part of estrus, when the female first becomes sexually receptive in each cycle, she copulates very freely with many males, including some of the older infants. But as she reaches the peak of estrus, she goes into a consort pair with one of the highly dominant males, and they go off together for some time (a few hours for baboons, about a week for chimps).

Goodall also reported recently on the development of aggressive patterns during the early years of life. For

example, a ten-month-old male infant has been filmed by Hugo van Lavrick showing typical threatening gestures in a context similar to those of an adult threat. These early aggressive patterns are much more characteristic of males than of females—and this is true of a great many primate species. Kinship is also important in the development of such behavior. A juvenile may threaten or attack chimps older than itself provided that its mother is near and that the mother's rank is higher than that of the victim. Adolescent males are often aggressive toward females when no higher ranking males are present, but they apparently restrain such behavior toward females when dominant males are present. As adolescent males mature, they tend to threaten the lowest ranking mature males and so gain admittance to the hierarchy of adult males. In general, adolescence is a turbulent, aggressive period among these chimpanzees.

The chimp community we studied at the Gombe Stream consists of about 50 animals. They live in a forested valley with open woodland high up. Over the ridges on both sides there are other groups of chimps. Very little is known about their contacts with the communities on the other sides, although such information as is available indicates that contact, when it does occur, is pretty tense.

Our chimp community breaks up in subgroups, most commonly three to eight animals, and sometimes even individual animals for short periods. Composition is rather fluid, although there are certain enduring groups such as the unit of a mother and one or more of her offspring.

One of the characteristics of aggressive display by adult male chimps is that their hair stands out, making the animals look bigger and more impressive. As part of the display a male may drag a palm frond, brandish it over his head as he runs, swing it, or even throw it at somebody.

An adult male who has been away from his particular subgroup for a day usually puts on one of these aggressive displays when he returns. It is very interesting that something like a decay of familiarity seems to occur in many primate species; a brief absence elicits patterns that one sees in more full-blown form with total strangers.

We observed and photographed behavior suggesting that "technical ingenuity" in aggressive displays may be a significant part of dominance behavior in chimps. Three years prior to our study, a large can had been left outside by the research workers. One of the males, named Mike, had at that time incorporated it in his display. He ran at it,

An aggressive display by a dominant chimp causes a frightened young male to climb 40 feet up a tree.

An adult male who has been away from his subgroup for a day usually puts on an aggressive display when he returns.

Here an adult male breaks off from a tense situation with another adult and attacks a mother with a ten-month-old infant clinging to her, giving her a severe beating. High-ranking males usually do not fight with each other.

In an effort to get a share of some preferred food, an experienced female approaches with arm extended, palm up, "fear face," and making a very distinctive panting. Her very slow, ambivalent approach may get her a bit of food.

hit it, started it rolling, and chased it. This action had a tremendous effect on the other chimps, and he very rapidly became the most dominant male—with much less fighting than is typically the case in dominance changes of this kind. Evidently there was nothing in chimp evolution to prepare them for the kinds of sights and sounds that he created with such displays. Three years later—with no intervening episode—we put the can back outside. We were curious about whether he would respond, and how long it would take him. It took him less than ten seconds from the time the can was put down on the ground to the time he took off after it and put on a similar display. All eight other animals within observation at the time ran off into the forest or went up trees. One young male climbed 40 feet and remained in the tree for eight minutes.

Bananas are made available from time to time as a very attractive dietary supplement for both chimpanzees and baboons in the area. These are tense occasions when a good deal of threatening goes on between males of similar rank. What happens typically is that one of them will break off prior to fighting (usually high-ranking males do not fight each other) and attack a smaller, weaker, or less mobile animal. We saw one of those adult males attacking a mother with a ten-month-old infant clinging to her, giving her a severe beating, mainly with his fists and forearm. He did this to the same mother-infant pair three times within a week in these situations of redirected aggression. On one occasion he actually knocked them out of a tree from a height of about 30 feet. Thus, the infant, though generally treated with great tolerance, is not always immune in these episodes of redirected aggression.

After a dominant male has established his control of the bananas, other chimps may try to get him to share with them. An experienced female, for example, may back up to him in a lowered posture. This is called presenting, and it is common in a number of primates in agonistic situations. After she gets up to him, he may put his arm around her waist and give her a hug or a pat on the head.

In the same situation a female might approach with arm extended, palm up, "fear-face," and making a very distinctive panting sound. The approach is ambivalent—three steps forward, two back, three forward, two back. It may take several minutes to cover about 30 feet. Again, he may pat her, and sometimes permit her to take a bit of banana.

In the middle of the day, even after a very tense, agonistic morning, a group of animals tends to seek proximity. They have the whole valley to choose from, but they seek out each other's company and move in close to each other for a rest.

The most organized hunting pattern known in any nonhuman primate has been described in the Gombe Stream area. Typically, this occurs when an infant baboon (or colobus monkey) gets isolated up a tree. One adult male chimp goes up after it, and two or three other chimps surround the base of the tree to fight off any adult male baboon who tries to defend that infant. If the chimps catch the infant, the male in the tree and the next one up will tear it apart, and two or three of these high-ranking males will begin to eat it immediately. There is enormous excitement as other chimps arrive and beg in the most extreme way for just a tiny bit. But if the same kind of animal is put out—freshly killed for experimental purposes— there is nothing like the excitement induced when they do their own killing, and they do not eat the carcass.

At the same time as chimp-chimp interactions are occurring, the chimps and baboons are contesting too, as for example when we made bananas available after about a week's absence. The two species clearly know each other well; the chimps are generally dominant over the baboons in this setting. Members of both species were anxious to get the bananas. Two highly dominant chimps, Mike and Goliath, got them most often. It was common to see an adult male baboon giving Mike a strong threat—a display of his canine teeth. Other male baboons join in the fray. The baboon technique is one of harassment, and they may keep up the pressure for a couple of hours. Now and again they get a banana peel, but not much more.

Despite a few baboon threats, Mike appeared to be so relaxed that he stretched out with a pile of bananas right by his belly. The baboons, smaller than the chimps but with enormous canine teeth, kept close by, frequently threatening. As they persisted in this menacing behavior, Mike's relaxation disappeared. He gathered up a bunch of bananas, put them on his lap, and sat on one of the banana boxes. (Often, if a banana is put down momentar-

1. When bananas are made available, chimps and neighboring baboons try to get the fruit. Usually, as here, the highly dominant male chimps get it, but the adult male baboons stay nearby, threatening.

2. Despite the baboon threats, one of the most dominant chimps is so relaxed that he stretches out with a pile of bananas right by his belly.

ily, a baboon will dash in close and grab for it and then dash away again.)

Finally, after about five minutes more, a baboon broke off and attacked an adult female chimp rather than one of the male chimps he had been threatening. She went up the tree, as fast as she could, and he went after her. Once in the tree she started striking down with her fist and hit him on the snout; and he came back down bleeding. No male made any effort to defend her, although in similar situations there is a good chance that a male would come to an infant's defense.

Infants, of course, eventually learn to defend themselves, and we observed one way they learn. We saw an older infant chimp (in the company of another chimp) wielding a ten-foot palm frond like a baseball bat against an adult male baboon that could certainly kill the infant in an isolated situation. He hit the baboon with good accuracy, and chased him off into the forest. What's interesting is that for two years this infant observed two older siblings in exactly this kind of behavior. Both older siblings were quite skillful in using palm fronds as weapons. The infant practiced that behavior initially in the most clumsy way after observing them at length, and he eventually perfected the skill at age 4, which is still a very young chimp. (They do not fully mature until 10 or 12.)

It is often said that the cues in all species but man are so clear and sharp that aggressive interactions can be fine-tuned so that serious injury hardly ever occurs. This is largely correct, but there's a tendency to exaggerate the point. When evidence of serious injury has been looked for systematically in recent primate field studies, it has been found to be rather more common. The cues that limit aggression usually work, but not always.

Grooming—taking the fingers and lips and going down through the hair to the skin in a deliberate, repeated way—is an important behavior pattern in limiting aggression. The high-ranking males get groomed a lot, but they tend to groom others rather less. In any case, grooming seems to have some kind of tension-relieving effect, whatever other hygienic functions it may have. Similarly, an experienced female can sometimes calm an excited, aggressive male by touching his scrotum.

3. *But as the threats of the baboons persist, the chimp, now less relaxed, gathers up his bunch of bananas and sits on one of the banana boxes, holding the fruit in his lap.*

Observational learning in a social context seems to be the principal mode of learning for the nonhuman primates.

Baboons are also present in the forest habitat. We wanted to compare these forest baboons with baboons living in a savanna (plains) habitat.

There are several reasons to study baboons. One is the adaptive process of the closely related baboon-macaque group, which has spread widely through Asia and Africa and a variety of habitats. Another is that the baboons are the largest of all the monkeys. A third reason is that they have a relatively great ground-living capability in a type of habitat, the savanna, that was probably crucial in the emergence of early man. These savanna-dwelling baboons spend much more time in open country at a distance from trees than the chimps do. Based mainly on the extensive field work of Irven Devore (Harvard), the late K. R. L. Hall, Sherwood Washburn, and Tim Ransom (Berkeley), plus our own observations, we can summarize the conditions under which baboon threat and attack patterns are likely to occur:

1. Protection of the troop by adult males against predators, such as lions and cheetahs.
2. Protection of infants, both by their mothers and by adult males.
3. Resolution of severe fighting within the troop by adult males.
4. Formation and maintenance of consort pairs at the peak of estrus.
5. Attainment of preferred sleeping sites in the trees, particularly in the presence of predators.
6. Acquisition of premium foods, such as figs, nuts, and bananas, especially when these foods are spatially concentrated rather than widely distributed.
7. Dominance interactions, especially in the presence of premium food, or scarcity of sleeping sites, or females in full estrus.
8. Exploration of strange or manifestly dangerous areas, which is a function largely of adult males.
9. Contact between different troops, especially if such contact is infrequent.

Even after a very tense, agonistic morning, these animals, with a whole valley to choose from, seek each other for an afternoon rest.

The baboons' habitat has tall grass in which predators can readily hide, so the problem of predator pressure is very different there than it is in the forest habitat.

To observe the baboons, we followed a troop of 42 animals of both sexes and all ages, who have spent their lifetimes together. It's largely a closed social system, but there is some transfer of males between troops.

At one point the troop met with a lioness hunting. When she appeared, 39 of the 42 animals broke for the nearest trees—about a half mile away—while three adult males stood their ground. And so, in a moment, there was a phalanx of adult males flashing those impressive canine teeth interposed between the lioness and the rest of the troop. This is a case where social organization clearly meets a survival requirement.

Most of the threat and attack behavior on the part of the female is elicited by some kind of interference with her infant; but both males and females will very stoutly defend an infant, especially if the infant is giving a distress call.

The two most dominant males in the troop, Alpha and Beta, rarely got into real fighting. Ordinarily they stayed 100 yards apart at opposite ends of the troop. Their only serious quarrels arose over premium foods.

An older infant we called Torn Ear spent much of his day observing Alpha, and he enjoyed Alpha's protection. Torn Ear was perfectly free to threaten much larger baboons with impunity as long as Alpha was nearby. Torn

Ear was also much bolder about approaching us than any other infant, again with Alpha nearby. He observed, he imitated, and he often practiced what he imitated of Alpha's behavior. This observational learning in a social context seems to be the principal mode of learning for the nonhuman primates.

Since various biological indices suggest a rather close relation of man with chimpanzee and gorilla, it is interesting to note several patterns of aggression that are especially prominent in one or both of these species. We mention three.

First, both chimp and gorilla show more elaborate aggressive displays than any other primate species. This rich repertoire of threatening actions might well be called intimidation display. Patterns of submission and reassurance also seem to be more elaborate in these species than in other primates, and more similar to those of man.

Second, in chimpanzees, technology (if I may call it that) is more advanced than anything observed elsewhere among nonhuman primates. Simple tools are made according to an established tradition and are used effectively. Both spherical and cylindrical naturally occurring objects are used in threat and attack, sometimes with considerable efficacy.

Third, attachments based on kinship strongly influence behavior over a large part of the chimp's life, quite possibly all of it. Among other influences, kinship attachments may well serve to increase threat directed toward animals that are not part of the kinship subgroup, and also protection of the offspring's aggressive ventures in early life by the mother and probably by older siblings as well.

Grooming is an important pattern for limiting aggression. Whatever other hygienic functions it may have, it seems to have some kind of tension-relieving effect. This grooming session is between two high-ranking males, and is taking place during prolonged tension involving bananas.

Research workers in the field of bird and rodent behavior have studied various environmental conditions that elicit threat and attack patterns. Among them is the crowding of strangers, especially in the presence of valued resources such as food, sex, or nesting locations.

Is this also true of primates? Does the conjunction of these three conditions become an especially powerful instigation to aggression? Our observations of chimps and baboons leads us tentatively to answer yes to these questions, supporting the recent observations of other workers who have conducted studies of primates in natural habitats and in seminatural settings and laboratory experiments.

At Holloman Air Force Base in New Mexico, the Wilsons have observed chimps in a desert compound. When an animal was taken out of the group for a few days, even though he was quite well integrated into it earlier, he was very likely to be attacked when he was put back.

At Stanford, Patricia Barchas has been studying aggression in newly formed rhesus-macaque monkey groups. She finds that fighting is most likely to occur in the first few minutes of their contact with each other, as the strangers are introduced, and then later when food is made available under these crowded conditions.

Southwick, working in Calcutta, has established base-line frequencies for each of 20 behaviors occurring in a

Among baboons and a variety of other species, stable, established groups tend to avoid each other, and there is a good deal of tension when they meet.

social group of 17 rhesus-macaque monkeys composed of adults, juveniles, and yearlings of both sexes. After the group had stabilized, new animals were introduced from time to time in the 25- by 40-foot enclosure. New juveniles were mainly attacked by the resident juveniles; adult females were most likely to be attacked by resident females; and new adult males were attacked mainly by the adult males. For each class of introduced animals, it was found that the class whose status was threatened most directly was most active in the aggressive responses to the stranger.

Southwick also reduced the space by half to determine if crowding alone, in a familiar setting, increases fighting. It did, but modestly. At least under the conditions he used, the introduction of strangers was a more potent instigation to fighting than crowding, although both had some effect.

Generally speaking, among the baboons and a variety of other species, stable, established groups in nature tend to avoid each other, and there is a good deal of tension when they meet. However, it has recently been found in the monkey islands off Puerto Rico that some males fight their way into other groups, then later—even years later—may help a younger brother to enter that group.

Also from the Puerto Rican monkey islands comes evidence that the size of a monkey group is correlated with its dominance. In general, the smaller groups give way to larger ones. If the disparity is great, there is not likely to be more fighting, unless the resources available to them are very condensed and crowded.

Are there any general aggressive patterns common to primate species that are relatively closely related to man? We can make a tentative list of such patterns, referring not to the threat and attack patterns per se, but rather to the conditions under which they most commonly occur:

1. Dominance-submission transactions
2. The redirection of aggression downward in the dominance hierarchy
3. The protection of infants
4. When sought-after resources are in concentrated or short supply—for example, premium food, or a female at the peak of estrus
5. The meeting of relatively unfamiliar animals—which may be individuals, subgroups of an established group, or intergroup contact
6. Defense against predators
7. Killing and eating young animals of other species
8. Terminating severe disputes among subordinate animals

Factors of this sort may well have given selective advantage to aggressive primates over millions of years, providing they could regulate their aggressive behavior. Until now most of the research has focused on the sources and instigation of aggressive behavior; future work will profit from paying as much attention to the regulation and control of aggressive tendencies.

Hormonal influences upon brain organization early in life have been shown to affect later aggressive and sexual behavior. The pioneering work in the area was done with rodents. For example, brief treatment of newborn female rats with testosterone results in a lifelong abolition of female sex behavior and a tendency toward male patterns of aggressive behavior as well. That work was later extended by Young, Goy, and Phoenix to rhesus-macaque monkeys. He gave testosterone in large doses to pregnant monkeys; if the pregnant monkey was carrying a female in utero, that female was to some extent masculinized by the testosterone, both in some anatomical and in some behavioral characteristics—for example, clitoral enlargement.

The females who had been androgenized by testosterone in utero were shifted in a male-like direction: They initiated play more often, then engaged in rough-and-tumble play more often, and they threatened other animals more often than females who had not been exposed to androgens in utero.

Eight such monkeys have been followed into adult life at the Oregon Primate Center in Beaverton. These eight animals show a good deal of threatening behavior as adults, although some other measures of aggression have declined over the years under the laboratory conditions that were employed.

It is plausible that processes of this kind may have continued to operate through the long course of human evolution. But because of the extraordinary learning capacities characteristic of our species, it seems unlikely that the early exposure of brain cells to male sex hormone would establish a fixed complex response pattern for a lifetime. It seems more likely that some general orientation would be influenced by the early male hormone so that aggressive patterns are in some way attractive and readily learned.

Is there any evidence at all of similar effects in human development? John Money and his colleagues at Johns Hopkins studied more than 20 girls who had been exposed

When the baboon threatens, whether for aggressive or defensive purposes, he displays impressive canine teeth.

to various androgens in utero. They differ from a non-androgenized control group in several respects. The androgenized girls tend to be described by themselves and others as tomboys; they prefer outdoor sports requiring a great deal of energy and vigor, prefer rough play, and prefer toys ordinarily chosen by boys, such as guns. These observations raise an important question and illustrate how a lot of inquiry from basic research on the biology of sex differentiation applies to an important human problem.

But surely the hormone does not act on some template for guns somewhere in the brain. How, then, could such an effect be achieved?

Recall the emphasis on observational learning in the social environment for nonhuman primates. It may be that if the attention of the young primate is drawn to one sex even somewhat preferentially over another, then a great deal of learning will follow from it, such as what kind of objects are characteristically used by members of that sex.

In nonhuman primates, and maybe in human infants and young children, we might learn something from experimental methods for analyzing the deployment of attention. It is feasible to expose isolation-reared monkeys to different kinds of stimuli to see if they prefer to look at certain kinds of stimuli rather than others. I predict, for instance, that if we gave an isolation-reared monkey the

Several of the recent field studies of primates have shown striking behavioral changes at adolescence, which presumably depend, at least in part, on the hormonal changes in the males.

chance to look at various pictures, which included rough-and-tumble play, that males would spend more time looking at rough-and-tumble play at some stage in their early development than females would. In any case, that is testable.

Something similar to that has been done by Sackett in Harry Harlow's Wisconsin laboratory. His experimental setup consisted of isolation-rearing for nine months, during which he showed the monkeys various pictures. The pictures included both monkey and non-monkey stimuli. The first point of interest is that they spend much more time in infancy looking at the monkey stimuli than non-monkey stimuli, including pictures of people. Within the monkey stimuli, one finding is particularly interesting in the context of this discussion. A full-face threat elicited a peculiarly strong response—vocalizations and what is described as emotional disturbance. The response to the full-face threat was particularly strong between two and a half and four months of age. Something about that stimulus complex elicits a very strong, emotionally charged response in the isolation-reared monkey. So it is not difficult to imagine how an infant, once his attention has been drawn powerfully to a certain kind of behavior, would go on to learn a great deal about it.

What can we say about the role of the early social environment in shaping the development of aggressive behavior? I have touched on it already, and Harry Harlow presented some relevant material in the preceding article. The isolation-reared animals that he talked about are generally highly fearful and prone to outbursts of violence. Also, the infants who experienced brutality from their motherless mothers were themselves significantly more aggressive during the eight months they were studied than were the infants raised by normal mothers.

Lately the isolation-reared primates have been followed to see what happens several years later—at puberty, adolescence, and adulthood. In at least some of the work coming out of the Wisconsin laboratories, it looks as if the aggressiveness does not spontaneously decline with the passage of years after the monkeys are brought out of isolation. Indeed, for some the aberrant behavior becomes more pronounced later in life. Perhaps the onset of puberty is partially responsible for this later exacerbation in males. It may be no coincidence that the onset of puberty in males is associated with a sharp rise in circulating testosterone levels and with heightened aggressiveness. Several of the recent field studies of primate species have shown striking behavioral changes at adolescence, which presumably depend, at least in part, on the hormonal changes in the males.

Lately developmental psychologists have been calling attention to the importance of observational learning in young children. The child between one and two years of age is a devoted watcher; observation and imitation may well be the principal modes of learning at that age. If the primate ethological studies are going to have a stimulating impact on human research, I think it would be particularly on studies of infancy and early childhood. In fact, McGraw in Edinburgh recently published a study of young children in which he applied quite directly the agonistic categories from field studies of nonhuman primates and found they worked quite well.

There is also the major line of inquiry that Bandura and his colleagues have conducted at Stanford over some years with three- to five-year-old children on susceptibility of children to learning aggressive patterns by viewing models who act aggressively. For example, in one experiment preschool children were exposed to a model attacking a target for only ten minutes in a laboratory situation; a control group experienced the same situation without an aggressive model. When the children were tested in the same situation six months later, those who had witnessed the attack were much more aggressive toward the target object than were the others. A ten-minute exposure enhanced physical aggressiveness in the same situation six months later.

In general, biological predispositions to learning aggressive patterns and exposure to specific social learning situations may interact to produce great individual differences in aggressiveness during later life. In analyzing such problems, the effective conjunction of biological and psychosocial disciplines, so far rarely achieved, holds much promise for future understanding. It hardly seems necessary to point out the aggressive tendencies of the human species today. Whatever adaptive functions such behavior may have served in man's evolutionary past, there is serious question about its utility in contemporary society. The risks inherent in such behavior have been greatly amplified within our own lifetime, and yet these problems at present attract only a modest amount of attention in the scientific community. It is difficult to imagine a more important area for research in the future. Let us hope that the biological and behavioral sciences in the next decade will really pursue these problems, which are so poignant in their human impact, so urgently in need of solution, and so pertinent to the concerns of our time.

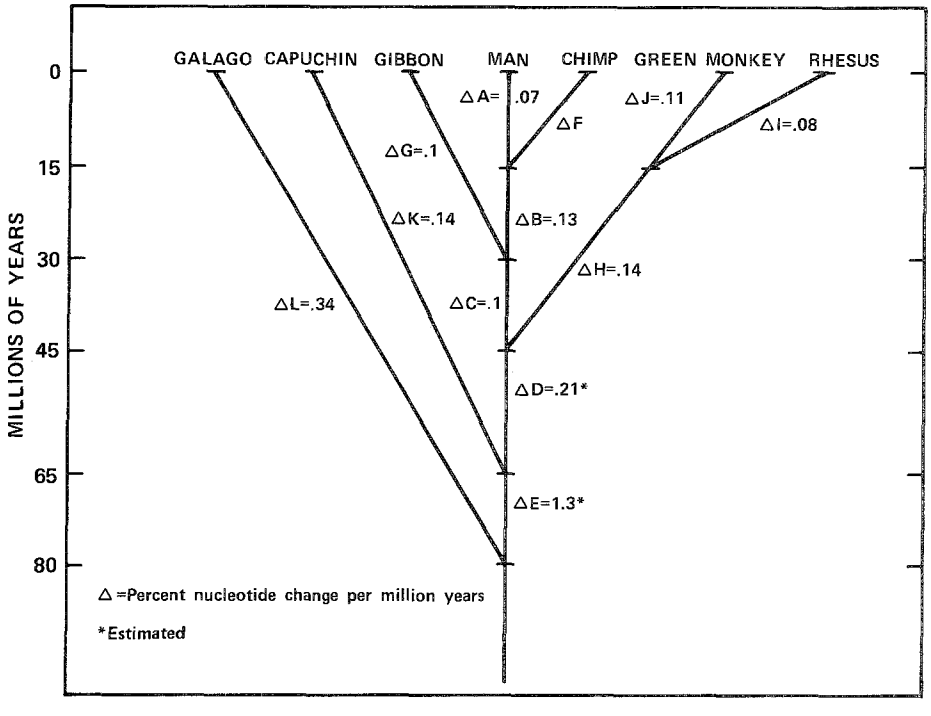
Excerpts from . . .

EVOLUTION OF PRIMATE DNA

By David Kohne

	Percent Actual Binding	Percent Normalized Reaction	$T_{50}R$	$\Delta T_{50}R$	Percent Nucleotide Change	Millions of Years Since Divergence	Total Divergence Time	Percent Nucleotide Change per Million Yrs.	Nucleotide PairΔ Changes Per Year
Man + Man	81	100	82.9	0	0	0	0	0	
Man + Chimp	76.5	94.6	81.2	1.7	2.6	~15	30	~.09	1.8
Man + Gibbon	73.7	91	78.8	4.1	6.2	~30	60	~.1	2
Man + Green Monkey	71	88	76	7	10.5	~45	90	~.12	2.4
Man + Rhesus	72	89	76.2	6.7	10.1	~45	90	~.11	2.2
Man + Capuchin	67	83	71.3	11.6	17.4	~65	130	~.13	2.6
Man + Galago	32	39.6	~47	~36	~54	~75	150	~.36	7.2
Man + Rat	10.3	13	—	—	—	~80-100			
Man − Alone	2	—	—	—	—				

Δ Assumes unique genome size = 2×10^9 NTP



The structural kinships of the DNA's of various primate species, as determined from the thermal stability of artificial man-primate hybrid DNA molecules (above), lead to the construction of a phylogenetic tree (left) showing when the different primates diverged from common ancestors.

Physiological and Psychological

by Carleton Gajdusek

Man in isolation is an imaginative cultural improvisor. His choice of independent routes of cultural evolution, more than his genetic variance, directs his behavior to diverse patterns.

We probably mislead ourselves if we hope from the study of contemporary primitive peoples to reconstruct behavior, conditions, and events in the ancient history of mankind. Many such peoples have histories as long as our own, only different. From the study of life in small populations with simple technology and uncertain and irregular food supply, under the constant threat of raids and warfare and of natural catastrophe, we may obtain ideas about the origin of our own societies. But these can

Most of the people living today in what we usually call primitive societies are on the island of New Guinea. This island, second largest in the world, harbors 2,500,000 people in over 400 separate cultures—each with its own completely distinct language.

Characteristics of Stone Age Man

only be suggestions, for we can never know in which ways the history of our societies paralleled those of contemporary primitive peoples.

However, observations of primitive peoples can provide us with new ways of thinking about human behavior. They may provide clues as to the patterns of input which determine the learning of specific behavior. They may inform us of possible varieties and extremes of human function which we would not otherwise imagine. Our view of the behavioral repertoire possible to man is extended.

Contemporary Stone Age man is no more uniform a species than is modern civilized man. Lack of breeding exchange between isolated "tribes," the varied selection pressures of different remote environments, and the large effects on such small communities of historical accident, the founder phenomenon, or of gene drift, have resulted in a wide genetic diversity of these peoples. There are great differences in physiological, anthropomorphic, and psychological characteristics and in the linguistic and behavioral characteristics among them. This is determined in part by the fact that man in isolation is an imaginative cultural improvisor, and has thus chosen independent routes of cultural evolution which have directed his behavior to diverse patterns more than has his genetic variance. The variations between different primitive groups scattered from the Arctic to the tropical climes, and from small atolls and islands to central continental plains and mountain ranges, indeed exceeds those encountered between civilized societies or between individuals within such societies.

Most of the people living today in what we usually call primitive societies, or Stone Age cultures, are to be found on the island of New Guinea. This island, the largest in the Pacific, the second largest in the world, and the central land mass of Melanesia, harbors 2,500,000 dark-skinned, spiral-haired native people who live in over 400 separate cultures, each with its own completely distinct language. The outlying Melanesian islands: New Britain, New Ireland, Solomon Islands, New Hebrides, New Caledonia, etc., together with New Guinea, contain over 700, or one-third, of the world's languages. It is in New Guinea and the surrounding Melanesian islands that I have had most of my experience with contemporary primitive societies.

Cannibalism and Headhunting

Cannibalism is both a trait of human societies and a behavior pattern found in many lower mammals. The incorporation of cannibalism into complex ritual behavior, however, is a particularly human trait; and, strangely, it is through cannibalism that we have the earliest evidence of ritual behavior in man. Paleolithic sites, from even 250,000 years ago, have given clear indication that man was already practicing ritual or symbolic cannibalism. The association of cannibalism with headhunting is close and has apparently remained a human trait from Paleolithic times through the present.

Kuru

All cannibalism in contemporary primitive cultures is not associated with headhunting. Many of the Highland populations of New Guinea, which have practiced cannibalism into the present decade, have eaten their own dead as a rite of respect and mourning for their close kinsmen. Thus, a remarkable fatal disease, kuru, which Dr. Vincent Zigas—currently director of the Malaria Service in Papua, New Guinea—and I found to be a plague and the principal cause of death among 30,000 Highland cannibal people in Eastern New Guinea's central ranges, attracted our attention. It was a new, rapidly progressive, subacute degenerative heredofamilial disease of the central nervous system, killing mostly women and children, decimating many villages in less than a decade, and leaving a male to female ratio of almost 3:1. The sheer magnitude of the fatal plague, killing over 2 percent of the population each year yet showing no associated high genetic advantage, made the apparent and strongly suggested genetic explanation of the disease untenable. For the first five years of our investigations, we could find no signs of inflammatory pathology, which was at the time of our investigations considered necessary if we were to entertain the suspicion of a viral or infectious etiology.

Kuru has been transmitted to the chimpanzee and the spider monkey using bacterial-free filtrates of tissues. We have now demonstrated that kuru is a slow viral infection. In fact, it is the first subacute or chronic degenerative disease of man of proved viral etiology. Its peculiar familial spread through the Fore population is now understood as the tragic outcome of contamination of the infants and children with infectious tissues of their dead relatives during the ritual cannibalistic rites of mourning.

Among the Marind Anim, a newborn child could not be named until a head was provided; the head was valueless unless the name of the previous bearer was known and the infant was given his name.

Brain tissue of kuru victims contains over ten million infectious units of virus per ml. The ritual butchery of the dead body was performed by women using their hands with sharp bamboo blades for knives while their infants were in their laps or crawling about. We must assume that the unwashed hands of the mothers contaminated in the cannibal ritual infected all their infants and toddlers by scratching or picking their sores, wiping their eyes and noses, and feeding them—with resulting accidental subcutaneous, conjunctival, respiratory, and oral infection. The steam cooking of the tissues at over one mile of elevation was not sufficient to inactivate the virus. Since the eating of the dead was restricted to close kinsmen, disease transmission followed familial lines. In fact, genealogical data still presents as good a case for heredofamilial or genetic etiology of the disease as is the case for diabetes and many other genetically determined disorders. The youngest patients were about five years of age, which is an indication of the shortest possible incubation period. It is often much longer, varying from five to over 20 years. In recent years the age of the youngest patient has increased, and now there are no cases of kuru in children below mid-adolescent age. We believe this is the result of the cessation of cannibalism about a decade ago.

It is tempting to hypothesize that the brain-to-mouth serial passage of a viral agent, perhaps well known and ubiquitous, has selected for a slowly proliferating neurotrophic strain which causes kuru. It is furthermore of interest that the genetic information transmitted to a child from his family and responsible for his later developing of kuru may have reached him from a sister or aunt rather than from his mother and father.

The study of kuru has resulted in the discovery that a group of fatal presenile dementias that occur throughout the world may be similarly transmitted to the chimpanzee, and in the demonstration that the measles virus causes the slow death of children throughout the world one to 15 years after they have suffered the acute disease.

Headhunting

In contemporary New Guinea only a few Melanesian cultures practice cannibalism—or practiced it in the recent past. Most, but not all, such cultures are headhunting cultures where the quest for heads is given more import than the ritual consumption of the carcass. In fact, in some cultures, such as the Asmat, eating of the dead bodies is not associated with unusual ritual, and the human meat is mixed with other meat from the hunt and with fish, rather indiscriminately.

The collection and use of heads, however, is of vast social and ritual significance. It is from the ritual use of heads and their collection that the paleontological record has revealed human cannibalistic ritual and human sacrifice in the Paleolithic times. It is thus tempting to draw parallels with the headhunting and cannibalism practices of current-day primitive peoples.

In order to release the brain from the cranial cavity, the skull must be smashed or otherwise opened in some way. In many parts of Melanesia, from the Solomon Islands and D'Entrastaux to Western New Guinea, this has been accomplished by mutilating the base of the skull of the victim by careful symmetric incising of the periphery of the foramen magnum. Such artifactual mutilation has been found in the Monte Carcao Neanderthal skulls of La Chapelle-aux-Saints and in the 11 mutilated skulls at Ngandong in Java. There is an even earlier find of such mutilation in skulls of Sinanthropus from a Choukoutien cave near Peking. The finding there of a further 40 skulls without fragments of other bones points to headhunting. Other faunal remains in the cave were represented by every part of the skeleton. Thus, from pithecanthropian times, over 250,000 years ago, through "early" and "late" Neanderthal and Bronze Age in Germany—where buried mutilated skulls also revealed the practice of ritual cannibalism—to the present, in recent headhunting from Melanesia, we have the survival of this very human ritual behavioral complex.

With the contemporary Stone Age peoples and those of the last few centuries, who practiced headhunting and the ceremonial use of human skulls or heads, the methods employed and purposes of the headhunting have been most varied. The intricate technology ranges from the production of shrunken human heads by the Jivaro in the Montagna of Peru, and the fine painting and decoration of heads in Melanesia, to the display of the enemy's skull on strings outside the houses or over graves or worn as neck pendants by the Asmat people. In New Guinea, dead relatives and ancestors are often remembered by

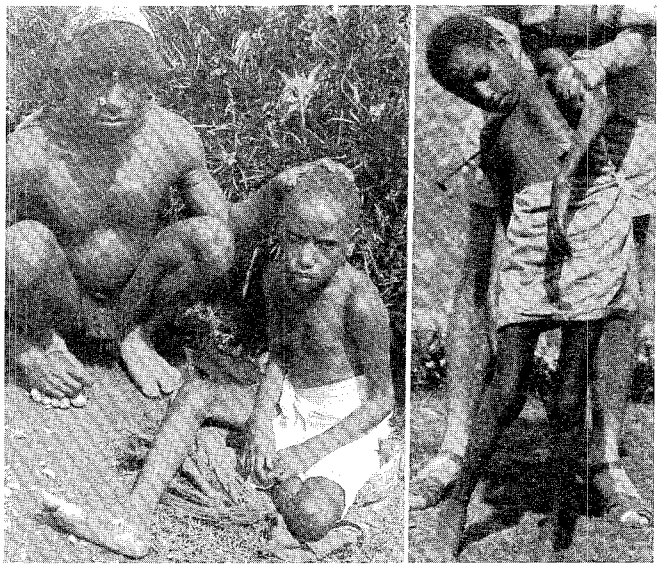
preserving their skulls, highly decorated with clay, red ocher, and shell, or beautifully hand-polished. More interesting than the different techniques of using the human skull is the complex social organization of head-hunting to serve different purposes.

Ritual headhunting occupies a complex position in the societies of the southern coast of New Guinea between the Purari delta and the Asmat and Mimika coasts. The motives for headhunting were many: revenge, aggression, to assuage a fear of insecurity, and the acquiring of prestige, but once undertaken, the headhunting acquired additional symbolic significance. In all cases the entire social order revolves around the practice with social status, age grading, and initiations depending on the headhunting complex. Cannibalism was incorporated into it, as was a complex pattern of fertility rites and sexual relationships. A group of southern New Guinea peoples (the Kiwai, Marind Anim, Fredrik Hendrik Islanders, Jaqai, Asmat, and the Mimika) form the largest headhunting complex on the island. Only the Marind Anim were so organized that they carried their raids beyond the frontiers of their own cultural and linguistic group, rarely raiding their own tribal neighbors. All other groups, however, raided those in adjacent communities of their own culture. Although raids were often carried out to avenge the death of kinsmen, which was attributed to the work of sorcerers in the raided community, the requirement for heads was determined by a much more complex social pattern. Thus, among the Marind Anim, a newborn child could not be named until a head was provided; the head was valueless unless the name of the previous bearer was known and the infant was given his name.

On Fredrik Hendrik Island the head was needed to hang over the grave of a recently deceased kinsman. Among the Jaqai a head was required by young men seeking marriage, for until their prospective spouses were presented with heads, they had not proved their manliness, nor provided a sufficient magical stimulus to fertility in their new wives. The adjacent Asmat father dutifully headhunted to assure the puberty and genital maturation of his pre-pubertal and early-pubertal son, who then slept with the head between his legs. The Asmat also hung the heads in their gardens to further the growth of their crops. The Kiwai attributed their headhunting to the need to promote fertility in their crops, especially sago.

Both in legend and recent practice the victims have often been guests who have been treacherously invited to feast or offered hospitality for the night. At other times, the victims have been allies who were duped into a rendezvous with their attackers, under the illusion that the two groups would proceed in unison to attack a third enemy group. The feigned alliance was established only in order to assemble the unsuspecting allies for their butchery. Coupled with the practice has been a diplomatic immunity afforded to the young men who have grown up bearing the name of victims after whose head they were named, or whose head provided for their pubertal growth. Such young men, in practice and in myths, were sent to receive special hospitality from the victim's group, a privilege to which they were entitled by their special relationship to the victim—through the use of his head. The purpose of their visit was recognized as that of espionage: an attempt to learn sleeping places, and the needed names of new potential victims. However, the cultural tradition and legend provided a precedent for such diplomatically immune spies to accept a wary, but warm, hospitality so thoroughly that they might turn on their own group, serving as informants to the enemy group they were sent to spy upon, in return for sanctuary and other reward.

The headhunting ritual was associated with dancing and feasting, periods of licensed sexual promiscuity, and the complex initiation and training period for young prospec-



Kuru, a fatal neurological degenerative disease in the New Guinea Highlands natives, has reached epidemic proportions through the rite of ritual cannibalism. The two children here are in the middle stages of kuru and already require extensive support. The child at the left falls over unless held upright by her father; the other child can no longer stand without support.

tive headhunters by older mentors, which usually involved an adopted father-son, and eventually homosexual, relationship. The failure to headhunt was considered to interfere with a man's fertility and his power to procreate. Most victims were well known and neighbors to the headhunters. Most interestingly, a vast ambivalence entered into the whole complex. The killing of an enemy was thus used to enhance genital growth and stimulate puberty, to endow fertility in a boy or girl, to bestow a name on an infant or novice, to avenge a death by sorcery, or to invoke fertility in the hunter, or a garden or sago planting. The headhunting thus coincided with weddings or ceremonials of initiation, and with mourning periods. The apposition of life and death, and the symbolic rendering of fertility and new life by the head of the dead victim, permeated the practice everywhere.

In the Asmat languages the human body is associated with a tree: the legs, the roots; the body, the trunk; the arms, the boughs; and the head, the fruit. We too use this metaphor: "trunk" for body and "limbs" for extremities. The "fruit of man" in Asmat is his head, enclosed, like fruits or nuts, in a hard shell like a coconut. Headhunters are called the "brothers" of fruit-gathering birds, fruit-gathering squirrels, and tree kangaroos.

As the fruit of a tree contains germinative power, so the fruit of man is collected and used to bestow germinative power on the boy's genitals, on crops, on the hunter, on his women. Here we see man doing what no lower animal does—using a ritualized signal as a metaphor, or a symbol which can be displaced to serve one and then another and yet another cultural need, as his imagination dictates.

When headhunting is unsuccessful and heads are scarce, a wooden head has been carved to serve the same symbolic purpose; and with the advent of missionaries, coconuts have replaced in displays, rituals, and ceremonies the head, which originally had symbolized the coconut or sago nut, metaphorically assuming the fertility endowed in these seeds.

In our own history the ceremonial display of human heads has not been without ample precedent: the Medusa of Perseus; Salome and the head of John the Baptist; the display of heads on pikes in England's War of Roses; skulls of martyrs in Catholic reliquaries; and piled skulls and altars made of skulls in the catacombs under the churches of Europe.

Garn and Black have recently pointed out that a grown "man a week" would only serve to provide a useful protein supplement to a group of about 60 people experiencing protein malnutrition. Zegwaard recorded that about 1 to 2 percent of the Asmat died per annum from headhunting before government administrative control of the area. The consumption of its own number of people per year would only just prescribe an adequate protein intake for a group. Thus nutrition is a poor excuse for cannibalism.

Cannibalism, and special attention to the human head with resulting headhunting, are two examples of the transformation of a primitive behavior complex into a signal, a process of ritualization. These ritual signals have then later attained symbolic meaning. Once ritualized and then given metaphorical or symbolic import, the new symbolic behavior can be incorporated into different cultures. The form is modified, and its content, purpose, and meaning are shifted, but most of the basic elements of the expressive behavorial pattern, not originally employed for communication purposes, are retained.

Slow Growth, Late Puberty, Early Aging, Short Stature, and Nutrition

The primitive or Stone Age societies of New Guinea exhibit a wide range of physical variability. This is reflected in differences in their outward appearance, anthropometric measurements, and studies of genetic pleomorphisms of red cell and serum factors, as well as in a number of biochemical differences in serum and urine specimens. The geographic isolation and restriction of each population to its own area, which may vary from tropical tidal swamps devoid of dry ground and stone, to high-altitude mountain valleys over 3,000 meters high where frost often endangers food supply, has produced very different forces of genetic selection and very different problems to be met by man's improvisations with cultural themes. Within these various ecological niches, enclaves of Neolithic man have diverged during their periods of isolation to their current-day status of great diversity.

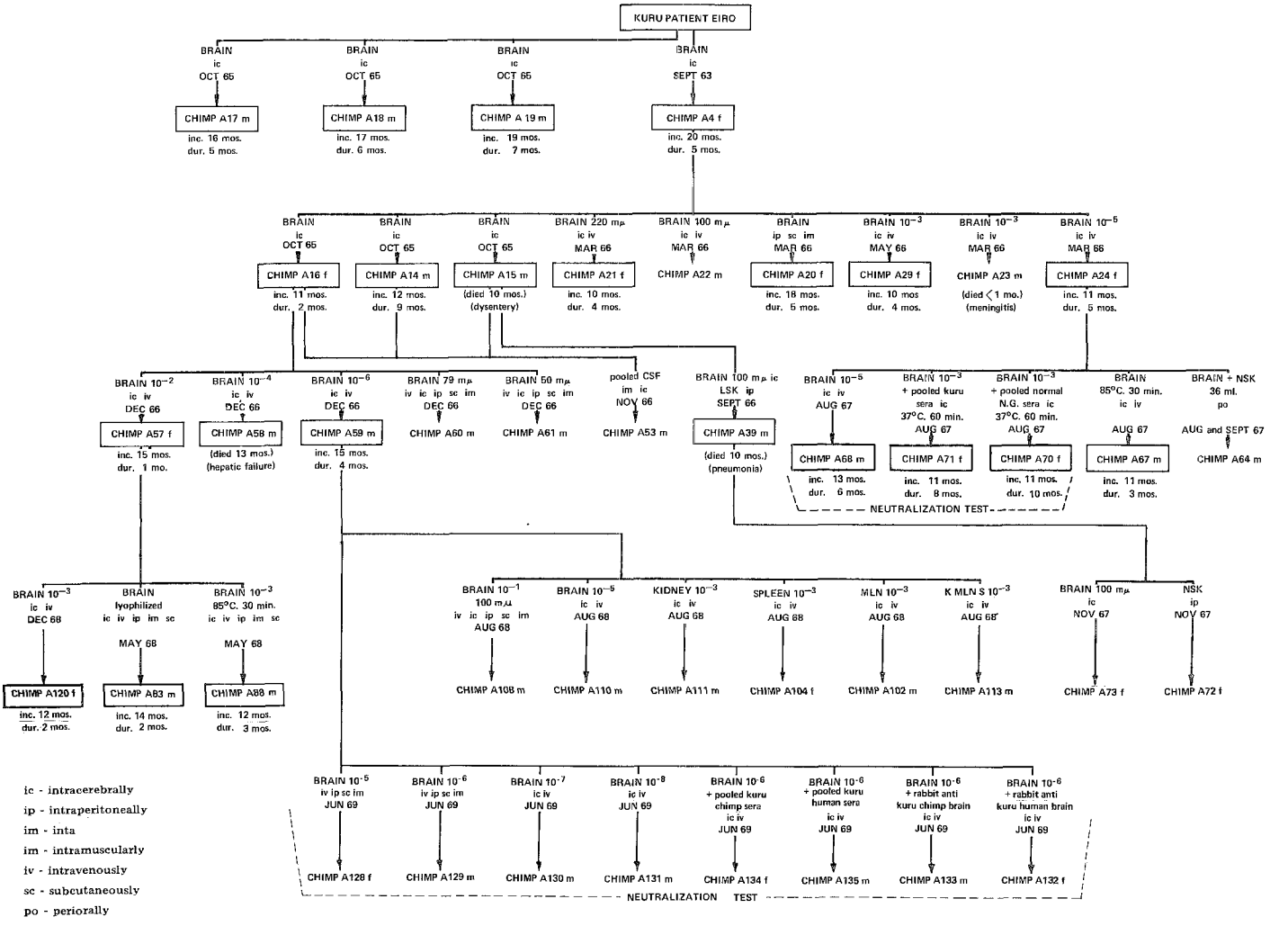
Retarded Puberty

Recent growth and development studies in isolated communities of New Guineans have revealed extremely slow growth patterns with very delayed puberty. In fact, the slowest child-growth rates on earth have been found in some of these short-statured communities, with early signs of puberty first appearing in girls and boys only at about 15 years of age and the menarche at over 18 years of age in many communities, and at over 20 years in some. This contrasts with the mean menarchal age of 12½ and 13½, respectively, in Chinese and English studies. Thus, with a short life expectancy, many New Guineans have spent over two-thirds of their life attaining full sexual maturity.

In our own history the ceremonial display of heads has not been without ample precedent: the Medusa of Perseus; Salome and John the Baptist; heads on pikes in England's War of Roses; skulls of martyrs in Catholic reliquaries . . .

The people exhibiting the most extreme growth retardation are regularly found to be suffering from malnutrition with low total protein and caloric intake, but often without overt clinical manifestations of malnutrition. Such communities have markedly increased disease susceptibility and very high infant and, especially, high toddler death rates. Protein-feeding experiments in schools and in labor compounds have demonstrated dramatic growth acceleration. It is thus a matter for further inquiry to know how much of the pigmoid habitus (build) of some New Guinean societies, in many of which the height and appearance of a 12-year old is that of a six-year-old European, is determined by genetic factors, and to what extent environmental factors, particularly nutrition, have contributed to this condition.

We have found unusually high pituitary growth hormone



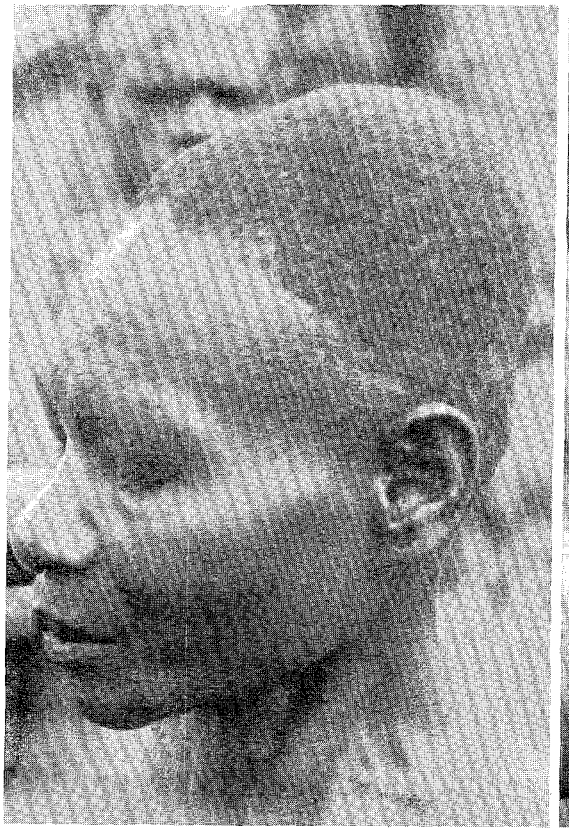
This diagram traces the transmission of kuru from the brain of a human patient, Eiro, through four generations of chimpanzees. Blocks indicate positive evidence of kuru based on clinical disease and histopathology or on histological findings in the absence of clinical diseases. Incubation period and the duration of clinical disease are shown as months after inoculation and months after onset of clinical signs until death.

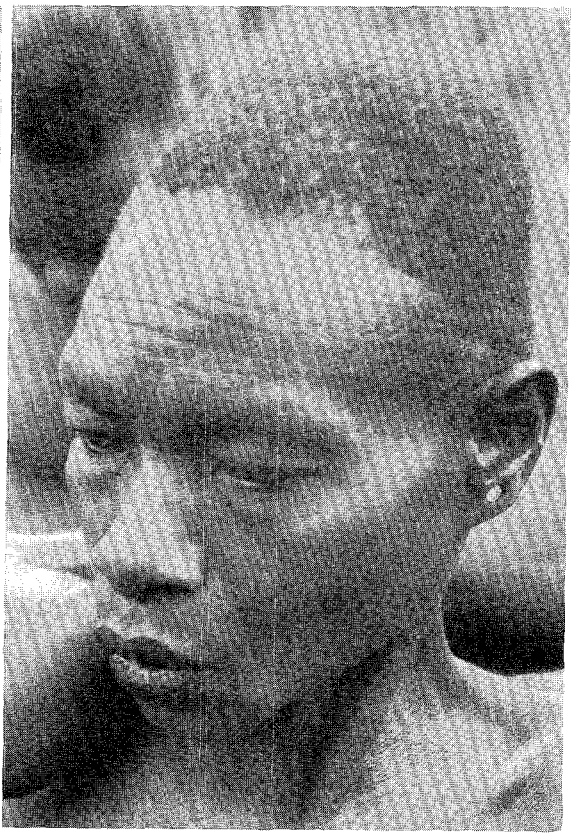
levels in autopsies done on young New Guineans, and Rimoin and Malcolm have found the highest serum growth hormone levels in man in these New Guineans. This may reflect a compensation for the low protein intake of these populations.

The life cycle of the Stone Age New Guinean thus starts with the lowest recorded birth rates for man, proceeds through a slow growth in infancy and early childhood at a slower rate than that found in any civilized culture to a delayed puberty, with final sexual maturation at the end of the second decade of life and with the prospect, then, of a reproductive life of only one further decade. Physiological childhood and immaturity are long; social and psychological childhood and dependency are short. Boys and girls 16 to 20 years old are easily mistaken, by European criteria of age, for children of 10 to 12.

Early Aging

However, adults past 30 often already look aged. There is a continued progressive decrease in weight and skinfold thickness with age that starts just after the attainment of maturity. Before the third decade of life one commonly observes wrinkles of skin on hands and feet and facies, and the appearance of excessive age in the face and hands and breasts of women. This "aging," however, is not accompanied by an atherosclerosis or the vascular changes and hypertension of aging civilized populations. Serum cholesterol levels are low, and blood pressure is low in adult life. How much of the entire pattern is the result of the peculiar New Guinean low protein, low fat, low caloric, high potassium/low sodium, high carbohydrate and high fiber/low sugar diet throughout life, we do not know. Certainly the growth and development of these children and their puberty are accelerated by protein supplemented diets.





Among the Mamusi people of the Central Ranges of New Britain, infants' heads are deformed for cosmetic purposes by a tight circumferential band wound around their heads each day (above). This long, backward-sloping forehead with an elongated skull results (below). The deformation produces no known neurological disability.

Sodium Deprivation and Low Urinary Output

Although coastal New Guineans have no dearth of salt in their diet, the landlocked people in the interior mountain valleys of New Guinea, not unlike those in the continental mountain ranges of Asia and of the Andes in South America, live in a sodium-scarce environment. Unfamiliar even with the existence of the oceans, they do not know of sea salt; yet they prepare a condiment of their own by burning sheets of pounded bark fibers which have been soaked in mineral springs, or from complex leeching of salts from ashes of burned reeds and bark, which contain more potassium and calcium salts than salts of sodium. It is not surprising, therefore, that we have found in these people a complete reversal of expected values for urinary sodium and potassium excretion from those of the civilized peoples of the world. In fact, so dramatic was this finding that, when we stumbled upon it, our laboratory technicians thought that the labels of the sodium and potassium value columns had been interchanged through clerical error. Their daily intake of NaCl of 40-70 mg is less than 1 percent of what is considered normal elsewhere. Their potassium intake is over four times that in civilized societies. Urinary K/Na ratios are often 200-500:1, or 400 to 1,000 times the expected so-called normal values.

Similarly, sweat of New Guinea highlanders contains less than one-tenth the amount of sodium found in normal people elsewhere in the world.

The excessively low salt intake, coupled with a daily protein intake often under one-third that which on European standards would be minimum daily requirement, leads to low values of nitrogen excretion, extremely low values of amino acids in the urine, and low urine sodium excretion. Thus, the astonishingly low urine output for many Highland peoples, and their lower sweating, can be more readily understood. In fact, lactating women and men on long journeys often drink little or no water, and inapparent evaporative loss through skin and respiration leave little water for urine production. Daily output values have been recorded at so low a level that one would anticipate uremia in a European on an average diet within a few days.

Optimal Habitus for Heavy Work Load

Life in the fortified stockaded hamlets, built on high narrow ridges for security against raids, is rigorous. Steep descents and ascents of over 1,000 meters must be made to the garden sites and sources of drinking water and firewood. Heavy loads of sweet potato and other tubers, firewood, and water-filled bamboo cylinders are carried up to the villages. A woman who weighs only 45 kilograms may carry a load of over 20 kilograms down and up the

Continued on page 56

Excerpts from . . .

Socio-Genetic Influences of Chromosome Complements

by Kennedy McWhirter

Accurate diagnosis of genetically influenced behavioral disorders is fundamental to the treatment of any kind of deviation. That these ideals have lapsed in a number of areas invites grave criticism of administrators, lawyers, politicians, and, not least, of the opinion-forming public . . .

The whole current concept of criminal responsibility rests on a logical fallacy, which has been incidentally exposed by the unresolved arguments over the status of subjects with the abnormal XYY chromosome complement. I propose a shift in the onus of proof from those who argue for some genetic component in criminality to those who claim that there is *no* genetic component . . .

For years, various sociological writers have quoted each other to the effect that crime is due to poverty. Several nations have enormously increased their standards of living recently, yet crime has not abated. This experience should have been enough to make the environmentalist penologists and sociologists reconsider their position—but this they show no signs of doing. Environmentalist penology has become a vast self-perpetuating and self-fulfilling industry . . .

Once we recognize that penology has no right whatsoever to assume completely environmental causation of crime, the way is opened for new and, we hope, more fruitful concepts. If we make the minimum assumption of some genetic influence, we are ethically precluded from dressing up our penal proceedings in terms of righteous indignation and retribution. Instead, our main concerns are the restitution of victims' losses (for the state has failed to protect its subjects), rehabilitation of the offender, and prevention of further offenses . . .

Where XYY subjects have developed a criminal subsyndrome, the uselessness of present "rehabilitative" methods has been acknowledged. It may not be different with appreciable portions of the far more numerous XY convicts . . .

The interactionist philosophy, of course, requires that society should not tolerate environmental conditions which can be shown to be conducive to crime. But society should also not tolerate the lazy acceptance of a system that is continually providing its own pernicious failure. Like so many other areas of behavioral studies (for instance education, alcoholism, and drug addiction) penology must now be converted into an interdisciplinary science. The exclusion of the natural sciences from such fields invariably leads to inefficient and inhumane policies.

Matched Pairs of Hermaphrodites: Behavioral Biology of Sexual Differentiation from Chromosomes to Gender Identity

by John Money

Gender-identity differentiation is programmed in humans to take place largely after birth, and also to be dependent to a large degree on stimulation from, and interaction with the social environment.

Gender identity in adulthood is the end product not of an either-or determinism of heredity versus environment, but of the genetic code in serial interaction with environment. From the time of conception, the genetic code unfolds itself in interaction, first with the intrauterine environment, then the perinatal environment, the family environment, and eventually the more extended social, biological, and inanimate ecological environment. Interactionism is a key principle, but an even more basic key is the principle of serial sequence of interaction.

Serial interactionism means that interaction between the genetic code and its environment, at a critical or sensitive developmental period in an individual's existence, from conception to death, may leave a permanent ineradicable residue upon which all else is subsequently built. This residue may be so indelible or insistent in its influence as to resemble the potency of the genetic code itself. Moreover, such indelibility or insistence may be residual to what has traditionally been referred to as learning—in which case learning should be referred to as imprinting, in recognition of the persistence and durability of its influence.

In a bygone era of medicine and behavioral biology, the differentiation of a person's sense of gender identity was confidently accepted as innately or instinctively determined. Among authorities of this bygone era, there was less confidence as to whether the innate determinism was genetic, gonadal (by reason of possessing ovaries, testes or, rarely, ovotestes), or hormonal. But there was an agreement of sorts, among these erstwhile experts. They wrongly agreed, in hermaphroditic cases of doubt owing to incompleted anatomical differentiation of the external sex organs at birth, that the sex of the gonads somehow had paramount importance in dictating what the sex of assignment and rearing should be. Therefore, they tried to palpate two testes—if not descended, then in the groin. These palpated lumps might be defective and infertile. No matter. The expert, in his ignorance, might omnisciently decree that an infant, despite a deformed hypospadiac penis resembling a mildly enlarged clitoris, be assigned and reared as a male—though Nature's effort to make a complete male had obviously been thwarted.

Today, one knows better than to use a single, dogmatic criterion, like gonadal sex, on which to base the decision of sex assignment and rearing in cases of congenital ambiguity of the reproductive anatomy. When all the variables, from chromosomal sex to fertility, have been properly evaluated and prognosticated, the one that

ultimately takes preeminence over all others is the criterion of erotic applicability in adulthood. It is useless to assign (or reassign) an hermaphrodite as a male, if all the medication, surgery, and psychotherapy in the world will fail to enable that individual to function in an adult erotic relationship as a male—and likewise in the case of female assignment.

Effect of Androgen Insensitivity on Differentiation

No matter what the genetically determined antecedents and components of gender-identity differentiation, the postconceptional and postnatal determinants can, in test cases, completely override them. The syndrome of androgen insensitivity (testicular feminization) in genetic males provides a graphic example of the extent to which the genetics of the sex chromosomes can be overridden in gender-identity formation. In this syndrome, suppression of the genetic program carried by the XY chromosome pair is itself a genetically transmitted trait. It has its effect at the cellular level by preventing cellular uptake of testosterone, the androgenic sex hormone of the male. The cells of the embryo and fetus are thus unable to utilize their quota of the testosterone released in normal amounts by the body's own testicles.

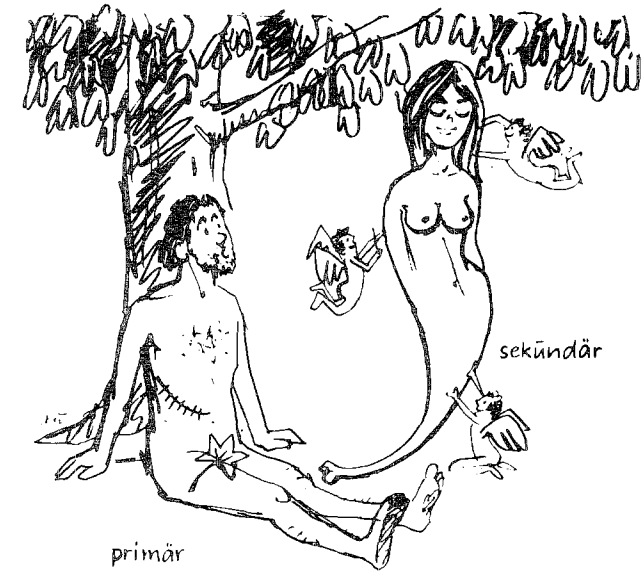
In consequence, the embryonic testes fail to inhibit, as they should, the primal tendency of the internal and external reproductive organs to differentiate as female. The failure is incomplete, so far as the internal organs are concerned, so that the uterus is poorly formed and incapable of menstruating at adolescence. By contrast, the failure of the testes to hormonally masculinize the external organs is total, with the result that the anlagen of these organs differentiate as 100 percent female. The baby is born with a female appearance so that, as for all babies with the same genital anatomy, she is announced and registered as a girl. It will not be until much later that a discrepancy will be recognized between the anatomical appearance, on the one hand, and the gonads and XY chromosome pattern, on the other.

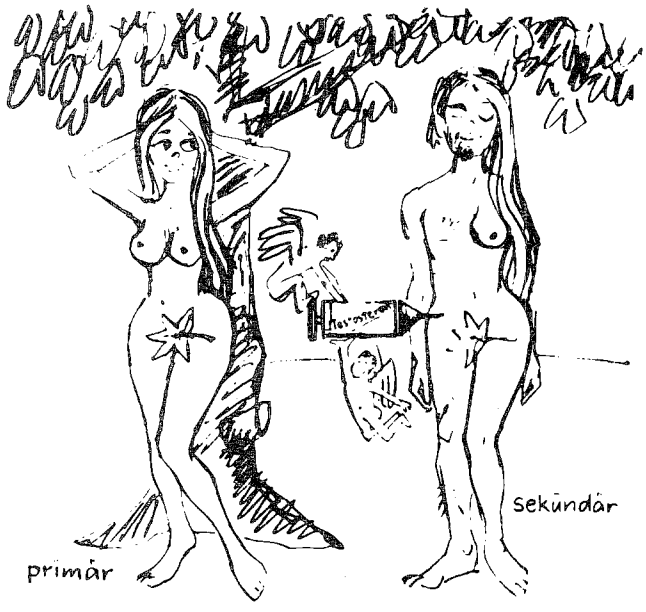
Very occasionally, the syndrome will be recognized in infancy, because of the appearance of the testicles as lumps in the groin, as they try in vain to descend. Occasionally also, an infant might be diagnosed in the course of a family checkup, when an adolescent sister has been diagnosed after a gynecologic examination for failure to menstruate. This latter age is, in fact, the most usual one when a diagnosis is made. By this time, the girl has developed her own breasts and a normal female body contour, for her body has continued to be cellularly unresponsive to male sex hormone, now being released in normal adult amounts by the Leydig cells of her own testes. Her body cells have responded only to the normal amounts of estrogen, the feminizing hormone, normally released by the testicles of normal males.

The girl with the androgen-insensitivity syndrome spends her infancy and childhood exposed to the same family and social influences as her normal sisters, cousins, and friends. She is reacted to as a girl, and she responds as one. Her gender identity differentiates as that of a girl. She shares the play interests of other girls her age, and in teenage she develops the same romantic and dating interests. Despite the bitterness and deprivation of infertility, and of knowing about it ahead of time, she typically gets married and achieves her motherhood by adoption. She is indistinguishable from other mothers on her street. No one, except her closest family and her medical advisers, knows, or even suspects, the uniqueness of her status as a genetic and gonadal male, though she is an hormonal, morphologic, and psychologic female. Her case is a prime example of how little the genetics program of the XY chromosome pair can achieve, of and by itself alone, when its proper developmental environment—cellular through social—is changed as a consequence of a quite limited biochemical impairment, itself genetically determined.

Experimental Antiandrogenism

Though a genetic factor is responsible for initiating the train of events that produces human beings with the androgen-insensitivity syndrome, an analogous condition can be initiated in animals with no abnormal genetic trait. In this case, the hormonal environment of the fetus is changed at a sensitive period, critical for the differentiation of the external genitalia, by injecting the pregnant mother with the synthetic hormone that has an androgen-antagonistic effect. The sons are then born with the external genitalia anatomy of the normal female. Their testes remain undescended in the abdominal cavity where, if subject to no further antiandrogenic treatment, they will secrete masculinizing hormone at puberty. However, masculinzation can be prevented by removal of the testes, and feminization can be induced by cyclic injections of estrogen and progesterone. Then the animals will go periodically into heat, as regular females do, and will respond sexually as females to the males that try to mount them. The males respond to them in the same way as they do to normal females.





Nature's first intention in sexual differentiation is to make a female. So perhaps the story of Adam and Eve might be retold, with Eve no longer being created from Adam's rib, but with Adam being made out of Eve by an injection of testosterone.

The feminizing effect of antiandrogen on the sexual differentiation of the male was discovered by Neumann and his colleagues in West Berlin. Their experiment illustrates the principle, first demonstrated by Jost in Paris some 20-odd years ago, that Nature's first intention in sexual differentiation is to make a female. Jost had castrated fetal rabbits in utero and found that all, regardless of genetic sex, were born with the morphology of females. With no gonads and no gonadal hormones at the critical period of fetal life, differentiation of the external genitals is always female. Something must be added, namely male sex hormone, usually supplied by the fetal testicles, to initiate masculine differentiation of the primitive anlagen of the external sexual organs.

Neumann illustrates this principle humorously when he says that the story of Adam and Eve really should be retold. Eve would be created first, instead of from Adam's rib. Then an archangel would appear with a big injection needle and, by injecting woman with testosterone, create man.

Male Hermaphroditism: Matched Pair

With this principle of masculine differentiation in mind, let me describe another kind of hermaphroditism in man—that of a genetic (XY) male who is defective in developing the clitoris small enough to qualify as feminine, or since it's a genetic male, one should say a penis large enough to qualify as masculine. Such an example was a baby assigned as a female and raised that way. The father considered it malpractice when his local gynecologist told him nearly 11 years later that he had a son instead of a daughter. Fortunately for the girl, she ended up at Johns Hopkins, where she was given surgical feminization in two stages—the first for external appearance at the age of 11, and the second at the age of 19 when her insufficient vagina was lengthened.

Hormone treatments can do a great deal when they are started early enough. In this case the girl was beginning pubertal masculinization when we first saw her. But by surgical removal of the gonads and, therefore, of the male hormones, and with female-hormone replacement treatment, by age 19 she was a good-looking, feminine-acting girl. She was in love with a boyfriend who was number two in her experience. When she came to the hospital, number one was so anxious to be reinstated after being jilted that he took his vacation and visited her every day while she was recovering from her vaginoplasty. She still turned him down! Her psychosexual identity, as this anecdote indicates, had differentiated effectively as female.

This girl's example shows how complete can be a transformation, under an experiment of Nature of this type. It demonstrates that there is no preordained, mechanistic relationship between the genetic and genital structure, on the one hand, and the masculinity or femininity of behavior on the other. This lack of a direct determinism between genetics, anatomy, and sexual behavior is even

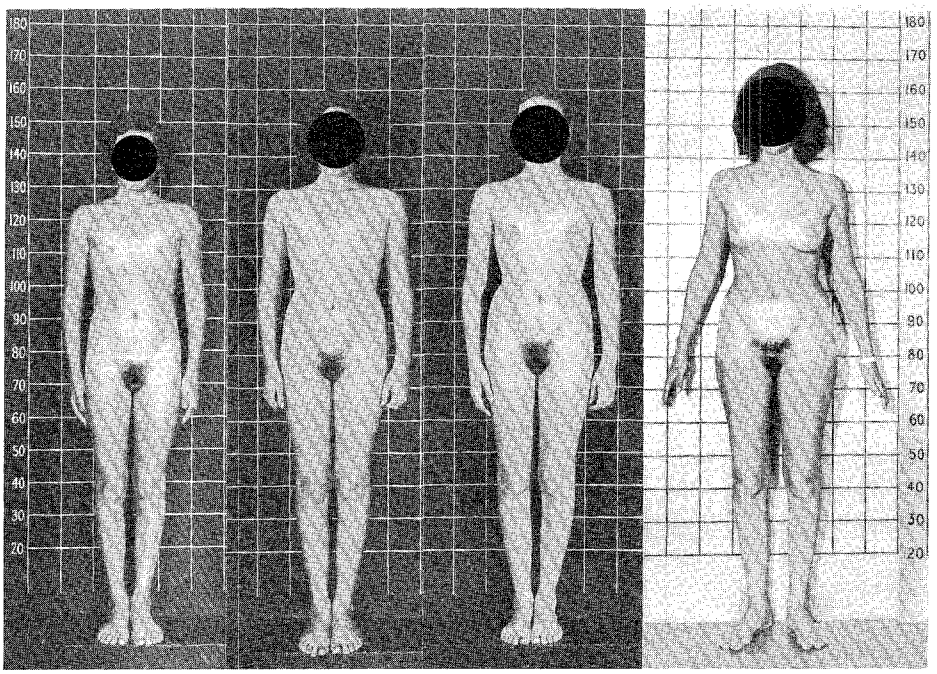
The father considered it malpractice when a gynecologist told him nearly 11 years later that he had a son instead of a daughter.

more vividly demonstrated when the case of the girl is matched against one of the same genetic and somatic diagnosis, in which the assignment and rearing has been not as a girl, but as a boy. This boy was recognized as genitally ambiguous at birth and, after some uncertainty, assigned as a male. Masculine repair of the genitalia required multiple admissions throughout childhood, and was finally successful, though the corpus of the penis is rather small. The testes at puberty secreted androgen in sufficient amount to induce spontaneous adolescent virilization. Fortunately the body was not androgen-insensitive, nor even partially so, with resultant breast growth and impotence, as is sometimes the case. The prognosis regarding fertility is unsure, as is the possibility of transmission of the genital defect to male offspring, should there be any. From infancy onward, the boy's psychosexual differentiation as manifested in his behavior, and in what he says, has been masculine. In adolescence, his romantic interests and imagery emerged as masculine. There was nothing that marked him as particularly different from his high school age mates.

The boy and the girl of the preceding case are theoretically important because of the sameness on which their differences are built. Both are genetically male with the XY sex-chromosome pair, and both were exposed before birth to the same fetal-hormonal environment. In infancy and childhood they were somatically similar, but they were exposed to quite different behavioral experiences. They developed correspondingly different behavior in relation to gender role and the differentiation of a gender identity. This remarkable antithesis in psychosexual (and sexo-behavorial) differentiation is indicative of a general principle: namely, that gender-identity differentiation is phyletically programmed in the human species to take place largely after birth, and also to be dependent to a large degree on stimulation from, and interaction with, the social environment.

Adrenogenital Female Hermaphroditism: Four Matched Pairs

The foregoing principle can be found illustrated also in matched pairs of individuals who are genetic females with the XX sex-chromosome pair. Let me now present four matched pairs of cases of female hermaphroditism of the type known as the adrenogenital syndrome. In this syndrome, masculinizing of the genetic female fetus is



This genetic (XY) male—shown at ages 11, 12, 13, and 19—was always raised as a female. At age 11 the mixup was discovered, and she got the first part of her surgical feminization; at 19 she received further feminization surgery. Her complete differentiation as a female shows how complete such a gender transformation can be.

"Dear Doctor,
I do not want to be a boy. I
want to be a girl, just like my sisters.
From Stanley"

initiated by a genetic anomaly that blocks the production of the hormone cortisone, in the adrenal cortex, and releases a masculinizing hormone instead. In a few rare instances masculinizing is so complete that the genital tubercle of the fetus develops not into a clitoris but a penis. The result is a genetic female born with a normal-appearing penis and empty scrotum. The tabs of skin that should form the labia minora of the female behave in the normal masculine developmental manner and wrap themselves around the protruding phallus to make a urinary tube in it. This genetic female will actually urinate through the penis. The outer swellings that should form the labia majora do the masculine maneuver of fusing in the midline to create an empty scrotum. Inside the body there are two ovaries and a uterus.

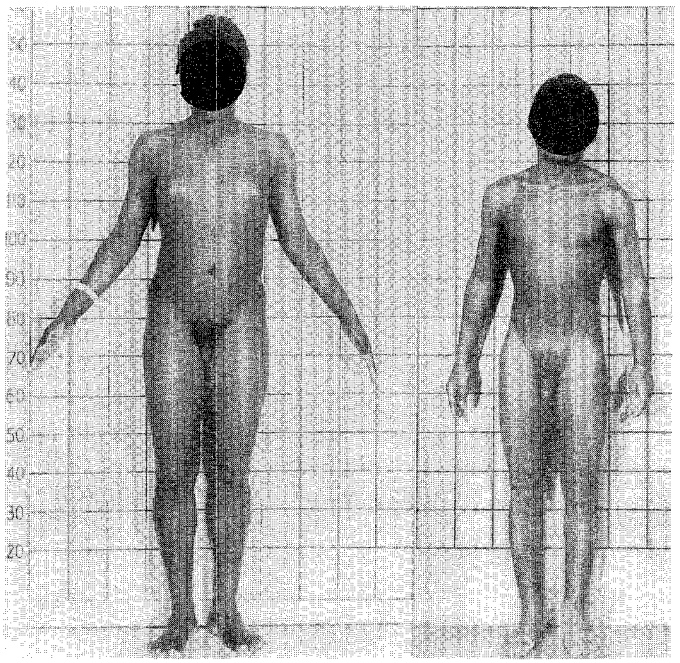
In the first matched pair, one baby was considered as a boy at birth. Coincidentally, symptoms of salt loss finally pointed the way to an accurate diagnosis, but too late to make a sex reassignment. The boy was allowed to stay living as a boy. Surgery was done in the masculinizing direction. The other baby, also because of acute salt loss, nearly died in the first few days after birth, and then was recognized diagnostically. After consultation with the parents (a very important thing, I might add, to get them to understand that doctors are not out of their heads when they tell them that their child with a penis is a girl), feminizing surgery was undertaken, and the baby was assigned and raised as a girl. Here again when two children have the same genetic sex, the same fetal hormonal history, and the same sexual anatomy at birth, it is possible to deflect one child to be raised and to develop a gender identity as a boy, and the other one as a girl.

In the second example, one child was again assigned as a boy and one as a girl. Each had masculinized external genitals, but not to the extent of a complete penis. We did not see them for treatment until they got to be around ten years old, by which time somebody had realized that something must be wrong. These were cases of imperfect, improper workup and diagnosis at the time of birth. When no treatment is given to genetic females with the adrenogenital syndrome, adrenal cortical androgen continues to be produced in excess and has its masculinizing effect—particularly noticeable by age ten as early virilizing sexual maturity. In the case of the child growing up as a boy, early virilizing was not too bad, but for the child growing up as a girl, it was a terrible mortification. The boy didn't like being sexually mature at so young an age, because no children like to be freaky and abnormal-looking, but at least he had the confirmation of being a boy. Nor did he like the final stigma of short stature, around five feet, as a consequence of early maturation.

Following diagnosis, both children had their careers continue unchanged, as boy and girl, respectively. The boy was able to maintain his body's masculinization, even without special treatment. Having had his penis repaired in childhood, he eventually got married. He did not keep his first marriage for too many years, but did not return to bachelorhood because of this, or feel that he was unmasculine. He tried again in a second marriage. Here is further evidence of the extraordinary importance and power of postnatal events and conditions in directing the differentiation of psychosexual identity.

The girl's story is opposite, involving hormone treatment with cortisone in order to permit the ovaries to produce feminizing puberty. Despite the years of hormonal masculinization, behavior outlook and ambitions were female in orientation. However, the girl's confidence as an erotic person, capable of an erotic life, and worthy of a boyfriend and a marriage was much delayed in maturing. (I've had to pilot quite a few of these girls through their anguish at feeling that they have a history of having been a freak, and that somehow this will be intuited by the boy who first has a sexual relation with them—that maybe he will find something wrong.) I have counseled this girl and her boyfriend, as they plan to get married, and she's finally triumphed. She's actually a very attractive young woman. The only telltale sign of her earlier medical history is a narrow configuration of the hips, because their fate was already settled by the time cortisone therapy was begun, owing to the years of the male-hormone influence on the fusion of the bones.

The next two people, who again have the same adrenogenital diagnosis as the previous four, were recognized at birth. They were given the modern cortisone treatment (discovered in 1950) to regulate the adrenal cortical glands and make them behave normally. Physically they both grew at a normal rate for childhood, without early virilizing, so ugly for a girl. At puberty, the girl got her breast development from her own ovaries, which were allowed to come into estrogenic hormonal action instead of being suppressed by malfunctional adrenocortical glands. The boy, also maintained on cortisone to regulate somatic growth, got his masculinization by being given injections of testosterone. He got his testicles implanted as artificial prostheses. His penis had been repaired earlier in life. The girl, at a time soon after birth, had had a



Both these people are genetic females with the adrenogenital syndrome. The one on the left was identified at birth as a boy, the one on the right as a girl. But in both cases the assignment was uncertain, and the uncertainty was conveyed to the growing children. Both, at age 11, changed their sex identity.

reconstruction of the vulva and vagina. Now both of these people have their romantic interests in teenage, appropriate respectively to their lives and roles as boy and girl.

There is a special, very fascinating point to mention here. This girl, like others of similar diagnostic and treatment history, has a certain special flavor to her behavior. Although completely acceptable as a female in our society today—not a lesbian, not falling in love with other girls—she is a tomboy and puts marriage second in her life. Also, she is very bright and has her sights set on a high-level academic career. (These people, by the way, tend to have high IQ's, which is probably related to the hormonal factor in prenatal life while the brain is being formed.) Maybe she will get married one day, and maybe she will have a child, but she's not strongly "turned on" by maternalism. Parenthood and a sex life are something that she can, without sacrifice, postpone.

The final example consists of two people whose position in life, by late childhood, was that somebody must have been a knave or a fool who put them in the wrong sex. As in the preceding six cases, each of them has the adrenogenital syndrome and is genetically a female. One, by age 11, thought he ought to change from being assigned as a boy to live as a girl; the exact opposite happened to the other one. In both cases, when the children were sent home from the hospital at birth, the parents were left with the uncertain possibility of a change of sex later, in view of the ambiguous appearance of the genitalia. Consequently, the parents did not know exactly what kind of child they were rearing—a boy or a girl. This type of uncertainty is as contagious as the measles, and the children contracted it.

Now, if you're a girl who is not sure that you're supposed to be a girl because of your funny-looking genitals, you have an alternative choice. It's a simple law of binary logic that, if you feel everything is wrong the way you are, maybe the correct way is the other way. I think therein lies the explanation of why both these children developed themselves in life as members of the sex other than that to which they were officially assigned. They finally reached the point where they felt that the only way they could belong to the human race was to be allowed to change. They both did, and now they both *do* belong to the human race.

In the course of their treatment I encountered two very telling documents. Both patients were electively mute on matters of sex; it was just too painful for them to talk about it. They were willing to be examined physically and to be cooperative in every way possible, but totally inhibited in the matter of talking. After about six sessions with the first of them, I found an illiterate note on my floor: "Dear Doctor, I do not wemt (want) to be a boy. I wemt to be a girl, just (like) my sisters. From Stanley."

I used this note as a parable, three or four years later, when talking with the other youngster who also suffered from elective mutism on matters pertaining to the dilemma of sex. From this second patient, among many other documents, I finally got one for the father and one for the mother. It was on a particular day when it was very important for the parents to get a message in person directly from the child, so they could be sure that their child was not being forced into a decision in the hospital. The situation was very tense and dramatic as this 11-year old, after a period of listening and doodling, finally wrote, with all the strength of his dyslexic and pre-primer level of achievement: "I gotta be a boy." Nobody had any doubts after that.

The lesson of my story of the four pairs of adrenogenital cases, each with the same genetics and each with the same prenatal history, is once again that—if we ever needed any convincing of it—one must always understand in matters of the biology of sexual behavior that a chain of interactive events leads from the genes to the final product. Only very rarely might one find a direct correlation on a cause-and-effect basis between genetics or any other single variable and behavior.

The Heritability of Intelligence

In accounting for the causes of the differences among persons in IQ, the genes outweigh the effects of environment by 2 to 1.

Since the dawn of history people have noticed differences in intelligence among individuals and have wondered about the causes of these obvious differences. Intelligence has been described by many different words—brightness, cleverness, reasoning power, judgment, and quickness in learning, in grasping abstract concepts, and in solving problems. Every parent, teacher, and employer has observed differences among children and adults in all these characteristics that we call "intelligence." A few persons appear extremely "bright," a few appear extremely "dull," and the vast majority falls somewhere between these extremes. There is a continuous gradation of mental ability from the one extreme to the other, from idiot to genius. Just as we see a continuous gradation of differences in other characteristics of humans, such as physical stature, so too there is a similar gradation of differences in intellectual ability. Indeed, individual variation is a fundamental aspect of all living things. Without individual variation, biological evolution as we know it could not have occurred.

The question of why people differ in intelligence has been asked for centuries, but a scientifically acceptable answer did not become wholly possible until psychologists devised techniques for measuring intelligence quantitatively and objectively. The first really useful intelligence test was devised in 1905 by the French psychologist Alfred Binet. Binet's early test was later revised and improved by Lewis Terman at Stanford University; the now-famous test that resulted from these efforts is known as the Stanford-Binet Intelligence Scale. It is still the most widely used test of general intelligence.

There are also many other intelligence tests, and although many of them appear to be quite different from one another, all actually measure much the same general ability. That is to say, if we administer several seemingly quite different intelligence tests to a large number of persons, their scores on all the tests will be in pretty much the same rank order. Those who score high on one test will tend to score high on the others, and those who score low on one test will usually score low on all the others. This fact of correlation among all tests of intelligence led Charles Spearman, the famous English psychologist, to conclude that there is a general factor, "*g*," which is common to all tests of intelligence. We know that it is practically impossible to make up a mental test having any degree of complexity which does not involve "*g*." We can perhaps most clearly characterize "*g*" as an ability for abstract reasoning and problem solving, for seeing relationships, and for grasping concepts.

A person's score on an intelligence test is usually expressed as an IQ (for Intelligence Quotient). The test is standardized in the general population in such a way that the average IQ at any age is set at 100, and the middle 50 percent of the population falls within the so-called average range of IQ's going from 90 to 110.

Significance of the IQ

Can the IQ tell us anything of practical importance? Is it related to our commonsense notions about mental ability as we ordinarily think of it in connection with educational and occupational performance? Yes, indeed, and there is no doubt about it. The massive evidence from psychological, educational, and industrial research, and research in the armed forces, is unequivocal. We know, for example, that no other single fact that we are now able to ascertain about a child gives us a better prediction of his future scholastic performance than his IQ obtained after age 5 or 6. (Below this age IQ tests become less accurate indicators of the child's later mental development, and below 2 or 3 years of age test scores have practically no predictive value.)

The IQ obtained after 9 or 10 years of age also predicts final adult occupational status to almost as high a degree as it predicts scholastic performance. When various occupations are ranked for average income and for the general public's average judgment of the occupation's prestige and desirability, this rank order is found to be highly related to the average IQ level of the persons in these occupations. There is of course a wide spread of IQ's in nearly every occupation, but the *average* IQ of persons within a particular occupation is closely related to that occupation's standing in terms of its average income and the amount of prestige accorded to it by the general public.

One of the most convincing demonstrations that IQ is

by Arthur R. Jensen

related to "real life" indicators of ability was provided in a classic study by Terman and his associates at Stanford University. In the 1920's they selected a total of 1,528 children with Stanford-Binet IQ's above 140. The average IQ of the group was 152. These children were investigated periodically over the years up into their adulthood. (Most of them are now in their 50's.) Terman found that for the most part these high-IQ children in later adulthood markedly excelled the general population on every indicator of achievement that was examined: a higher level of education completed; more scholastic honors and awards; higher occupational status; higher income; production of more articles, books, patents, and other signs of creativity; more entries in *Who's Who;* a lower mortality rate; better physical and mental health; and a lower divorce rate. Also, they have much brighter children than the average; their average IQ is 133, a level which is exceeded by only 2 percent of children in the general population.

Findings such as these establish beyond a doubt that IQ tests measure characteristics that are obviously of considerable importance in our present technological society. To say that the kind of ability measured by intelligence tests is irrelevant or unimportant would be tantamount to repudiating civilization as we know it.

The Causes of IQ Differences

The layman usually asks: "Is intelligence due to heredity *or* environment?" The scientist promptly answers: "Both." Without heredity *and* environment there simply is no intelligence. Obviously every person must have had a biological inheritance of genes from his parents and must have grown in an environment, or he wouldn't even be here to take an IQ test. So, of course, both heredity and environment are essential for the existence of the individual or any of his physical and mental characteristics.

But when scientists actually study this problem, we find that they do not even ask the layman's question. The question to which scientists have sought an answer can be stated as follows: How much of the *variation* among persons in a given population is attributable to differences in their environments and how much to differences in their genetic endowments?

Numerous studies conducted by psychologists and geneticists over the last 40 or 50 years provide an answer to this question. The answer is unambiguous and is generally agreed upon by all scientists who have considered all the evidence. This evidence strongly supports the conclusion that genetic factors are much more important than environmental influences in accounting for *individual differences* in IQ. How much more important? The evidence indicates that genetic factors account for at least *twice* as much of the variation in IQ's as environmental factors. This conclusion has one main limitation. Since all of the major studies in this field were conducted with samples of Caucasian European and North American populations, we cannot confidently generalize their conclusions to other populations, especially those with very dissimilar environments.

What are the kinds of evidence that lead to the conclusion that genetic differences outweigh environmental differences in accounting for individual differences in IQ? Most of this evidence, as it is found in the scientific literature, depends upon quite technical methods of analysis developed in a specialty known as quantitative genetics or population genetics. Some of these methods were devised originally to analyze the roles of heredity and environment in agriculture and animal breeding.

Experiments in Animal Breeding

Experiments in which we explicitly try to breed for some specific trait give us the most certain evidence that variation in the trait has a genetic component. Psychologists have bred rats for speed of learning mazes, which is a good indicator of rat intelligence. By always mating the fast-learning males with fast-learning females, and mating slow-learning males with slow-learning females, it is possible, within 6 to 10 generations, to produce two quite distinct strains of rats in respect to maze-learning ability. The slowest learning rat of the "bright" strain will learn mazes faster than the fastest rat of the "dull" strain. The two strains will differ markedly in the number of tries they need to learn how to run through a maze efficiently, avoiding the blind alleys. These experiments definitely prove that not only physical characteristics but some behavioral traits as well are largely inherited through the parental genes. Thus we should not be surprised to find in humans that differences in some behavioral characteristics, including intelligence, are a product of genetic inheritance.

Identical Twins Reared Apart

One of the most important lines of evidence for the inheritance of intelligence in humans comes from studies of identical twins who were separated shortly after birth and reared in different homes. Identical twins originate from a single fertilized ovum which splits in the course of

Identical twins reared apart differ,

on the average, by only 6 to 7 IQ points.

early development to form two individuals. Each member of the pair of twins therefore has exactly the same complement of genes. Consequently, any difference between the twins must be due entirely to nongenetic or environmental differences.

Twins separated shortly after birth are often reared in families that differ markedly in social class, and the range of environmental differences observed in their foster homes is fairly typical of the environmental variations seen in the general population.

Four major studies of identical twins reared apart, conducted in England, Denmark, and the United States, and totaling 122 pairs of twins, are in remarkably close agreement in showing that twins reared in different homes are still much more alike in IQ than are *fraternal* twins reared together. Fraternal twins are merely siblings who happen to be conceived and born at the same time, and therefore half of them are of opposite sex. In IQ and other traits they resemble one another no more than do ordinary siblings born at different times.

Identical twins reared apart differ, on the average, by only 6 to 7 IQ points. But even if we test the very same person on two occasions a week apart, we find that his test score will vary, on the average, by 2 or 3 IQ points. This is the test's "measurement error." When we eliminate this error from the twin data, we find that the twins differ only 4 or 5 points in IQ. Identical twins reared *together* differ by only 2 or 3 points, not including measurement error. The largest IQ difference ever found in a pair of identical twins reared apart is 24 points. More than 17 percent of siblings reared together differ by more than 24 IQ points. The same is true of fraternal twins. But siblings (and fraternal twins) have only half of their genes in common, and they differ on the average by 12 IQ points (excluding measurement error), even when reared together.

The studies of identical twins show clearly that individuals who are genetically identical are almost as much alike in mental ability as they are alike in physical traits, and this is true even when they have grown up in different environments.

Unrelated Children Reared Together

The opposite situation to identical twins reared apart is that of genetically unrelated children adopted at birth by foster parents and reared together. Such children differ from one another, on the average, by 15 to 16 IQ points (excluding measurement error). Compare this with the 17 to 18 IQ points difference between unrelated children reared in *different* homes, or the 15 to 16 points difference between unrelated children brought up in different homes but in the same socioeconomic class. We see that unrelated children brought up together in the *same* home differ from one another in IQ at least 3 or 4 times more than genetically identical twins reared in *different* homes. And the unrelated children reared together differ almost as much in IQ as unrelated children simply picked at random from different homes.

The IQ's of adopted children also show little or no relationship to the IQ's of their adopting parents, but they are almost as closely related to the IQ's of their natural parents as we find in the case of children who are reared by their natural parents.

Children reared in the common environment of an orphanage differ from one another in IQ to approximately the same degree as children picked at random from the total population. The IQ's of orphanage children who have never known their own parents show almost the same degree of correlation with their parents' level of ability as we find in the case of children reared by their own parents.

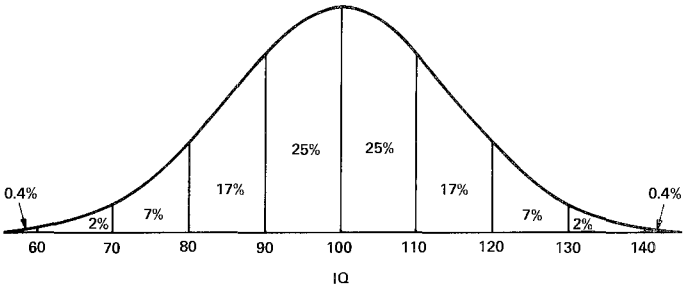
Resemblance Between Parents and Children

Now and then we notice that very bright parents can have an intellectually mediocre child, or that rather dull parents can have an exceptionally bright child. These observations are often pointed to mistakenly as evidence that intelligence is not inherited. But the fact is that genetic theory predicts precisely that we should find such discrepancies between parents and their offspring. For example, parent-offspring differences in height are of about the same relative magnitude as their differences in IQ. Children resemble their parents physically and in mental ability to about the same degree that they resemble their own siblings. The average IQ difference between a parent and his (or her) child is the same as the difference between siblings—that is, about 12 IQ points. The difference between a child and the average of both of his parents' IQ's is about 10 points.

A parent with a high IQ will usually, but by no means always, have children whose IQ's are somewhat lower than his own but are still above the average for the general population. A parent with a low IQ, on the other hand, will usually, but not always, have children whose IQ's are somewhat higher than his own but are still below the average of the population. This phenomenon, discovered by Sir Francis Galton, is called "regression toward the mean," and it holds true for height and other inherited physical traits as well as for IQ.

IQ's of Husbands and Wives

It is interesting that in our society husbands and wives are at least as much alike in IQ as brothers and sisters.



The theoretical normal or Gaussian distribution of IQ's shows the expected percentages of the population in each IQ range. Except at the extremes (below 70 and above 130), these percentages are very close to actual population values. (The percentage figures total slightly more than 100 because of rounding.)

If men and women picked their mates strictly at random, as by a lottery, spouses would differ by an average of 18 IQ points. But in fact men and women choose one another partly for intelligence, and so spouses differ by only 10 or 11 points in IQ.

The Effect of Inbreeding on IQ

Every person harbors a number of mutant, recessive genes. Most of these are defective genes. They are passed on from parent to child, but they usually will not produce any harmful effects to the child unless the other parent also contributes exactly the same defective gene. The reason this usually does not occur is that each parent's normal genes are dominant over the other parent's defective, recessive genes. When mating occurs between a man and a woman who are blood relations, however, the chances are much greater that they will both possess many of the same defective genes. When these defective genes are paired together in the related couple's children, they subtract unfavorably from the traits that are controlled by these genes under normal conditions. This depression due to inbreeding is known to occur in inherited physical traits, such as stature, and the same thing has been found for IQ. It is well established, for example, that cousin marriages produce children who, on the average, have IQ's several points lower than the IQ's of children whose parents are unrelated but are matched with the married cousins on IQ, age, educational level, and socioeconomic status. More extreme are the cases of children who have resulted from incestuous relationships, such as father-daughter and brother-sister matings. These children show a much higher incidence of severe mental retardation than children born to the same parents when they have mated with unrelated persons. These interesting findings are entirely predictable from basic principles of genetics that apply to all living beings. Moreover, it is virtually impossible to explain such facts without concluding that IQ differences are very strongly influenced by genetic mechanisms.

The Relative Effects of Heredity and Environment

How can we summarize briefly what is now known about the relative importance of heredity and environment in causing individual differences in IQ? In the terminology of genetics a summary answer consists of saying that the "heritability" of IQ is close to 0.80. This means that 80 percent of the "variance" in IQ's in the general population is attributable to genetic differences and 20 percent is attributable to nongenetic or environmental differences.

"Variance" is essentially a quantitative index of the total amount of differences that exist among all members of some population. So instead of talking about variance, we can more easily describe our conclusions in terms of average differences.

If we should determine the differences in IQ between every person in the population and every other person, the average of all these differences would turn out to be 18 IQ points. These differences are due both to genetic and to environmental factors. Now we can ask theoretically: What would be the average IQ difference among all persons in the population if everyone had grown up in identical environments from the moment of conception, while genetic differences remained as they are? Under this hypothetical condition of completely equal environments for everyone, the average IQ difference would be 16 points. Thus, there would be a reduction of 2 points in the average difference that now exists. Let us now ask the reverse: What would be the average difference if everyone had exactly the same genetic endowment, but environmental differences remained unchanged? Under this hypothetical condition of complete genetic equality the average IQ difference among persons would be only 8 points, or just half the difference that would exist with equal environments.

So the conclusion we come to—which is certainly valid at least in the white European and North American populations in which the research was conducted—is this: In accounting for the causes of the differences among persons in IQ, the genes outweigh the effects of environment by 2 to 1. As environmental conditions are improved and made more alike for all persons in the society, the average intelligence level of the population will be somewhat increased, and the IQ differences among persons will be slightly reduced. But of course the differences that remain will inevitably be due even more to genetic factors.

Excerpts from . . .

The Nature of Human Variation

by Richard Lewontin

If IQ had been under natural selection of any intensity at all during the course of human history, all that additive variance should be gone.

The problem of assessing genetical variation in human populations is the same as for almost any other species. Our predictive theories—those which tell how genetical variation has accumulated, what is responsible for its present status, and what the future of genetical variation in a population will be—are framed entirely in terms of the frequencies of allelic substitutions at various loci [*alleles* are alternate forms of the same gene—for example, that which determines eye color]. To describe the genetical variation in populations in terms of those substitutions is a very difficult and, in fact, at the moment, impossible job . . .

In an attempt to measure allelic substitutions that have small effects on the phenotype [the appearance of an organism resulting from the interaction of the genotype and the environment] a number of people in the last few years have taken to trying to characterize the enzymes and proteins that are the direct products of gene action and to characterize them by their physical-chemical properties, which, although they may not have any marked effect on the phenotype of the organisms, are sufficiently marked in their effect under laboratory test conditions so that you can detect differences in different individuals. That is, you try to find a system which allows you to detect the differences in physical-chemical behavior of proteins despite the fact that the organism itself cannot detect them. That's what molecular biology does for us.

The result of this kind of study in a variety of organisms—mice, *Drosophila*, and so on—is to arrive at an estimate of what the typical genome [a single set of chromosomes] of a typical individual in a typical population looks like.

Excluding man for the moment, and thinking only of *Drosophila* or mice, which are the two best documented cases, we find that, as a minimum estimate, something like 40 percent of all the structural genes in the genome of a sexually reproducing species have some significant genetic segregation in any population; and that the average individual is himself, or herself, about 15 percent heterozygous [having dissimilar pairs of genes at some loci, only one of which can be transmitted to progeny]. So that each one of us, if we have, say, 10,000 genes, is a heterozygote at 1,200 to 1,500 of those loci . . .

How heterozygous is man, if we assume that human blood groups are a random sample of the human structural genome? . . .

What we can do is to estimate the proportion of all genes that are polymorphic (that have more than one allele in them) cumulatively . . .

The estimate of the average heterozygosity per individual appears to be leveling out at about 16 percent. And the average frequency of polymorphic genes per individual is leveling out at about 37 percent. That figure is remarkably like the figure from mice and from *Drosophila*. That is to say, between 30 and 40 percent of all genes are polymorphic, and something like 12 or 15 percent of every locus in every individual is heterozygous.

This, then, is the kind of information that gives you a solid picture of the amount of available variation on which natural selection and human evolution can operate . . .

I think we should stop talking about vast numbers of genes controlling traits, all genes being of equal effect. For behavioral characteristics the real facts of life may turn out to be that four, five, or six loci will turn out to contribute 80 or 90 percent of the variance for a behavior trait, and the rest of the genome contributes the 10 or 20 percent. I propose that if anybody is really interested in doing the genetics of behavior in any organism that is manipulable by genetic tricks, the first thing that must be done is to establish the dose-response curve for genome against variance . . .

R. A. Fisher, the British statistician, enunciated what he called the fundamental theorem of natural selection, in which he said, in effect, that during the course of selection, either natural or artificial, so-called additive variance is used up. Eventually, equilibrium gene frequencies are arrived at in which all of the additive variance is gone and the only variance left is the interaction variance and the environmental variance.

Now when we come across a character that has vast quantities of additive genetic variance, our first suspicion is that this character has never been under natural selection; or at least if it has, it has been under natural selection only very weakly or for a very short time. As a matter of fact, a character whose additive genetic variance is on the order of 50 or 60 or 70 percent of all the variance is a very unusual quantitative character. If IQ has indeed got 50 or 60 or 70 percent additive genetic variance, then I wish to call into question very severely our notions about the adaptive significance of this variation of intelligence. Because Fisher's fundamental theorem, which is only approximate but still qualitatively true, tells us that if IQ or the performances that we measure by IQ tests had been under natural selection of any intensity at all during the course of human history, all that additive variance should be gone. I leave it to you then to ponder on the meaning of the very large amount of additive variance for IQ . . .

The important genetic discovery of Thomas Hunt Morgan and Calvin Bridges, something which population genetics in general does not take into account, is that genes are *not* floating around as individual particles. If you make a theory of population genetics that includes the fact that genes are organized on chromosomes, then you get the curious result that no single locus can be shown to have any important natural selection, that the chromosome will evolve as a kind of block by the accumulation of very small effects, and that natural selection may be operating to stabilize the frequency of the genes within a population. But one will not find that out by examining the effect of a simple locus substitution at a single locus. One has to take into account the entire chromosomal array.

HUMAN PURINE METABOLISM AND BEHAVIOR

By William L. Nyhan

One genetic disease of human metabolism, which results in degradation of mental and neurological functions, has been traced to inactivity of the enzyme HGPRT.

Genetic disorders of purine metabolism have been known since antiquity. Gout was recognized by Hippocrates, who identified it as a disease of the adult male. It occurs occasionally in the female, but under these circumstances she is usually old enough to be postmenopausal. However, there are not any 100 percent rules in human biology or medicine, and it turns out that there are a number of disorders of purine metabolism that appear early in life. At least one and probably more of them has a characteristic pattern of abnormal behavior.

The Greeks considered gout to be a product, as it were, of Bacchus and Aphrodite. We now know that gout is not acquired but rather is an inherited disease. At the right is a partial list of some persons who have been important to the development of western civilization who have also had gout. The frequency of the disease in the general population is only two per thousand. The association of this disorder with the qualities of behavior that lead to success are too high to be fortuitous. There are other recent data which make the same kind of point. And I think this story hasn't been told completely yet.

These considerations with regard to classic gout involve intellectual superiority or perhaps behavioral successes. The patients we have studied, on the other hand, have been severely mentally retarded.

The first patient we studied with a disorder of purine metabolism in childhood was four years old and quite seriously mentally retarded. He had not learned to walk, and could not even sit without support. He kept his fists tightly clenched, which suggested that he had a neurological abnormality. All of the patient's muscles showed a severe degree of increased muscular tone—as did those of all of the patients we have studied. This is typical of a child or adult with a severe degree of spastic cerebral palsy.

Also, these children are in continuous motion, displaying the abnormal posturing that has been characteristic of all of the patients with this disease that we've studied. The movements are typical of the neurological abnormality called chorea and also of athetosis. So these patients have chore-athetosis. In this way a clinician builds up the picture of patients' behavior into what might be considered a syndrome. We now have some kind of information on more than 100 patients with this disease. In virtually all of them IQ's are less than 50. So these patients are mentally retarded, have spastic cerebral palsy, and have chore-athetosis; this, then, would be a clinical or neurological syndrome.

It was when we saw the brother of our first patient that we began to think we were dealing with a genetic disease. He was eight years old at the time and showed the same features we saw in the other patients. He couldn't sit up, and his legs tended to assume a scissor position, which is characteristic of patients with very severe degrees of cerebral palsy or spasticity.

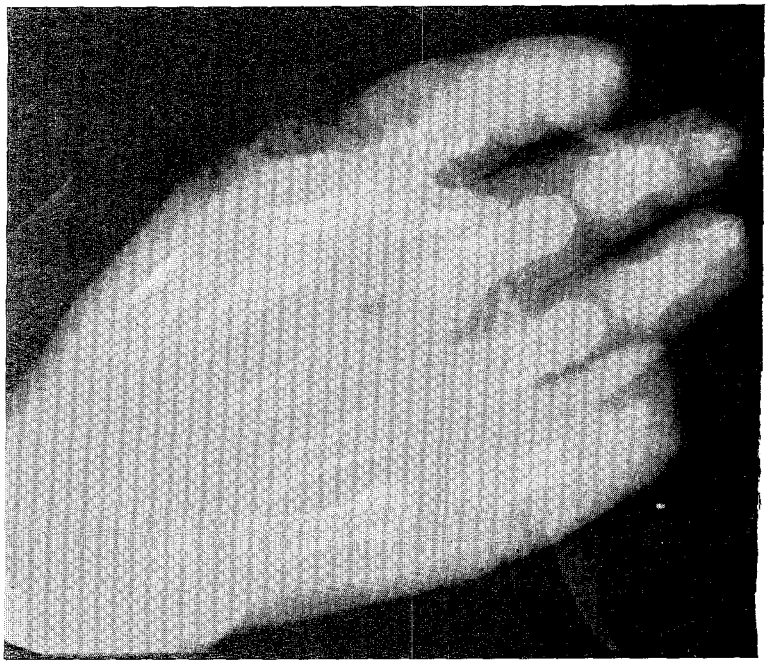
Many children with the disease look, I think, quite a bit smarter than someone with an IQ of about 50. Generally, as you see patients with the disease in the wards of institutions for the retarded, you get the feeling that they're smarter than the other children there. They seem to have a better capacity somehow in ways that we aren't very well able to test—possibly because they are prevented by

GOUT AND GREAT MEN

Alexander the Great	Thomas Gray
Isaac Newton	Goethe
Charles Darwin	James Russell Lowell
William Harvey	Alfred Tennyson
Benjamin Franklin	Edward Gibbon
Martin Luther	Henry Fielding
John Calvin	Horace Walpole
John Wesley	Samuel Johnson
Cardinal Wolsey	Lord Chesterfield
John Milton	Francis Bacon
Ben Johnson	Stendhal
William Congreve	Guy de Maupassant

Total incidence of gout: 2/1000 population

The enormous oversynthesis of purine is a basic metabolic defect which tends, to some extent, to establish the abnormal biochemical milieu under which these patients have had to develop and in which they must live day by day.



Self-mutilation is a typical syndrome of the disease. This Xray shows how one young patient actually bit off part of his little finger—bone and all.

their neurological abnormality from doing very well on a test procedure. The other thing you might see is that they have really nice smiles, an index of a sense of humor, which in turn is an index of intelligence.

All of our patients have related unusually well to people. In a hospital or in an institution it is very common for them to be the favorites of the nurses, the aides, and the attendants.

The most startling characteristic of the syndrome is that the patients often show self-mutilative behavior. Just recently, for example, at the University Hospital in San Diego we admitted a boy who had produced dramatic mutilation of a finger and thumb by biting. In fact, he managed to produce a partial amputation of a finger, bone and all.

We might think that a child who does this to himself would have a neurological abnormality in which he felt no pain. In fact, we have seen quite a number of children who have abnormalities of sensation. But those children are different. They look like pugilists, and might come in with a broken leg or jaw and not even be aware of it. Or they get burns around the hands because they put them in places they can't detect as dangerous. But they don't produce this very specific self-mutilation. Furthermore, we've now tested sensation extensively in children with this syndrome, and sensation is intact to anything we can test. These children don't like this behavior any more than we do or their parents do. We often have to wrap a patient's hands to protect them. If we slowly remove the wraps, immediately it looks to him as though he's no longer protected from himself; he becomes terrified. Nevertheless, if he isn't restrained, he begins to tear at his flesh with his teeth. These children cry when this goes on, but nevertheless, in an obsessive fashion, they still do it.

The clinical hallmark of the disorder is self-mutilative loss of tissue of the lower lip. The patient bites his lip to a point where he has a new mucocutaneous junction that is no longer accessible to his teeth. Interestingly, all of the damage in one patient might be to his lower lip; another might, for some reason, be dangerous to himself only in the upper lip, one thumb, or one finger.

The most dramatic example of the problem was first reported by Dick Haefnagel at Dartmouth, and we studied this patient on a number of occasions in Miami. A clinician seeing him first would probably think that he had been born with a hare lip and a cleft palate, but he was born completely intact. All of the loss of tissue was secondary to his own mutilative behavior. It points out, of course, that biting is not the only form of self-mutilating activity these patients engage in. He obviously did some of the damage with his fingers. We have seen children who have learned to lacerate themselves with braces or catch themselves in the spokes of a wheelchair. One patient who learned to get about in a wheelchair succeeded in scalding himself at a hot water faucet and on another occasion in producing burns with a dry ice and acetone mixture left by a dermatologist planning an experiment in the clinical research unit. The variety of this kind of behavior is in general limited only by the usually limited ability of these children to get about.

It has become apparent as we study older children that their behavior is not always addressed only against themselves. They'll bite other people; they'll hit other people. Doctors and nurses working with them count on losing a certain number of pairs of eyeglasses. The children learn how to use speech aggressively, particularly using words that they learn people find unacceptable. Many of them have learned to pinch nurses and other ladies, sometimes men too, in places that are not too acceptable socially.

The concentration of uric acid in the blood is probably the most frequently detected clinical expression of chemical abnormality in purine metabolism. Some years ago Dr. Jay Seegmiller in the *New England Journal of Medicine* indicated that most adult males have a serum uric acid concentration in the blood of about 5 mg/100 ml. A diagnosis of gout is supported by concentrations of over 6 mg/100 ml. Most of the patients we have studied have had uric acid concentrations in plasma that are in the vicinity of 9 to 11 mg/100 ml. But that doesn't indicate anything special about the condition, because in general a uric acid level of about 9 to 11 reflects the limits of solubility of urate in plasma.

When one studies an abnormality in metabolism and detects an elevated concentration of something in the blood, the next approach is to look at the excretion in the urine. We ran some tests in which the patient was allowed to ingest no exogenous purine; the urate excretion then was an index of how much purine was made by the body. Under those circumstances most adults have less than 500 mg of urate in the urine in a 24-hour period. Furthermore, adults with gout have about the same amount. This is one of the things that for many years led people to think that gout was a disorder of renal tubular excretion because there weren't large amounts of purine showing up in the urine. On the other hand, a smaller group of gouty adults, known as hyperexcretors, excreted more than 600 mg of urate in the urine in a 24-hour period.

Children tend to have somewhat less urate in the urine than adults, but that's because they're smaller. On the other hand, many of our 15-kilogram pediatric patients have so much extra urate in their urine that they could be called hyperexcretors even if they were 70-kilogram adults. This excretion, and hence production, of urate is enormous.

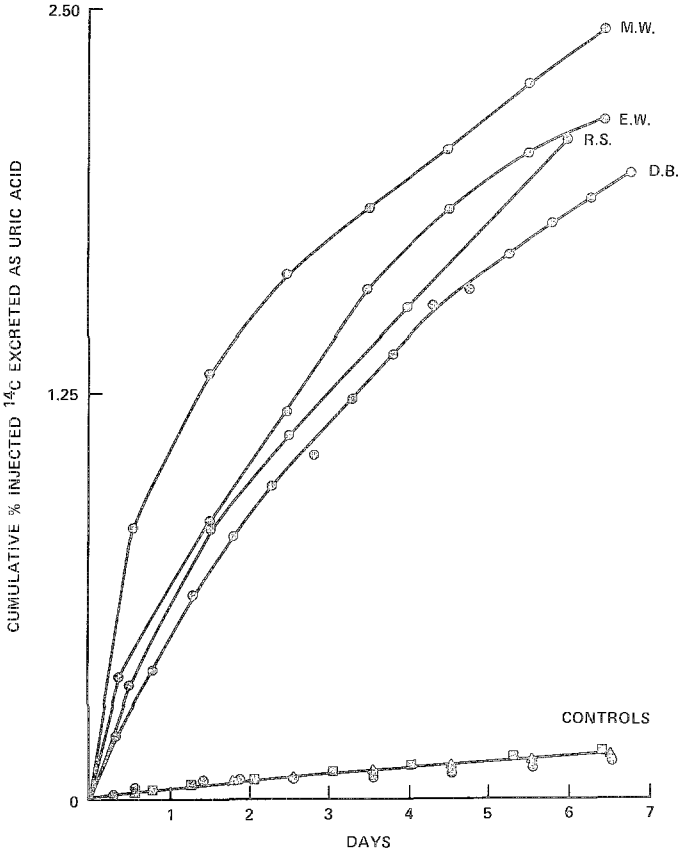
The classic way in which patients with gout have been studied chemically is to exclude exogenous purine from the diet and then to inject them on Day 0 with a small tracer dose of glycine labeled with carbon 14. In the body the glycine is synthesized into inosinic acid, which then shows up in the urine as uric acid. In a normal person about 1/10 of 1 percent of the glycine is excreted in uric acid in one week; our patients introduce somewhere around 2 percent of the glycine administered into the purine nucleus in the one-week period. Actually, most of the production goes on in the first 12 hours after injection. This enormous oversynthesis of purine is a basic metabolic defect which tends, to some extent, to establish the abnormal biochemical milieu under which these patients have had to develop and in which they must live day by day.

If our patients had large amounts of urate in their urine and blood, and had this enormous overproduction, one would then expect that they would have all of the

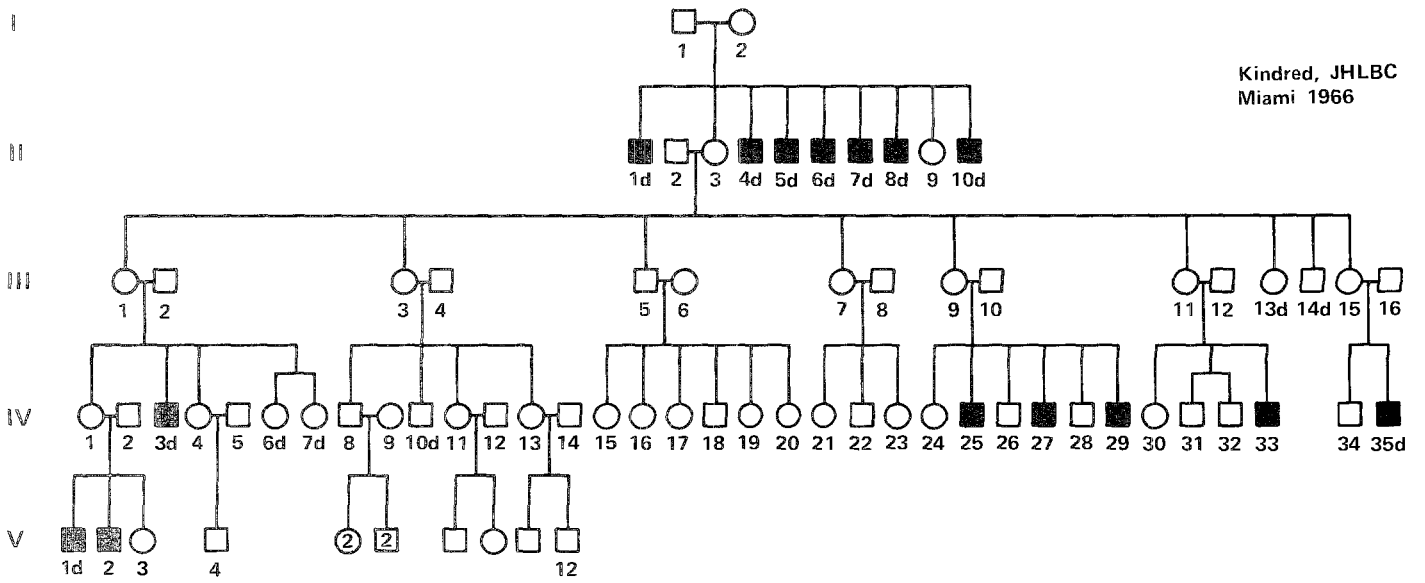
URIC ACID EXCRETION

	No.	MG/Day	Range	MG/KG/Day
CONTROL ADULTS	4	370	325-455	5.3
GOUTY ADULTS (Normal Excretors)	14	408	253-514	5.8
GOUTY ADULTS (Hyperexcretors)	4	754	587-1054	10.8
CONTROL CHILDREN	3	233	176-289	10.3
PATIENTS	2	690	669-712	45.3

The amount of urate in the urine of the children with the disease is almost as much as in the urine of hyperexcreting, gouty adults. A current hypothesis is that the abnormal behavioral characteristics represent the action of some chemicals that are a consequence of this enormous overproduction of purine.



When patients are put on purine-free diets and injected with radioactively labeled glycine (a simple amino acid), they produce about 20 times (2 percent versus 1/10 percent) the normal amount of purine in the urine in a one-week period.



This genetic chart of the family of the first patient studied clearly shows that over five generations the transmission of the disease has been through the females (circles) to the males (squares). The siblings under study are represented at the lower left.

clinical manifestations that one sees in adults with gout. In fact, they do.

Gouty arthritis is the caricature by which gout tends to be known. In general that symptom appears near age 50. Earlier in a patient who was to develop gout, somewhere around 15 to 20 years of age, there would be some elevation of serum uric acid. A urinary tract stone might occur at age 40. There are variations, but that's about the usual pattern. The children we study are producing much more purine than the average adult with gout, so the schedule is foreshortened. We have found stones in patients only a few weeks old. We have seen three teenagers with gouty arthritis.

The next chapter in this story involves the effects of the immunosuppressant azathioprine on purine metabolism. When we studied this agent in a man who had gout, he had a serum uric acid in the vicinity of 10 mg/100 ml. We gave him an enormous dose of azathioprine, which is the classic immunosuppressant used in transplanting kidneys and hearts. Sure enough, in about two weeks he was pretty well suppressed, and by that time his serum uric acid was down to normal. Azathioprine inhibits the synthesis of purine. Then we tried it on the types of children we've been discussing. The experiment was exactly the same as before, and we also started with a serum uric acid of about 10 mg/100 ml. We gave a similar dose of azathioprine. The uric acid level did not go down. These children are resistant to the action of azathioprine.

This was the key to the molecular basis of this disease, and it was first worked out by Drs. Seegmiller, Rosenberg, and Kelley, who at the time were at the National Institutes of Health. When azathioprine, which is a derivative of 6-mercaptopurine, is absorbed into the body, it undergoes a hydrolytic reaction, leaving 6-mercaptopurine to circulate. From experiments with leukemia on mice and men, it is known that 6-mercaptopurine is not active by itself, but must first be activated by an enzyme known as HGPRT. This enzyme is called hypoxanthine guanine phosphoribosyl tranferase, because it catalyzes the conversions of hypoxanthine and guanine to their respective nucleotides, inosinic and guanylic acids. It also converts 6-mercaptopurine to its ribonucleotide, after which it will work on cancer cells, and it will work as an immunosuppressant, and it will work on patients with gout. So one can say a patient resistant to the action of 6-mercaptopurine might have something wrong with this enzyme. This has been found to be the case. Analyses indicate that the enzyme HGPRT is 100 percent inactive in patients with this mutant gene.

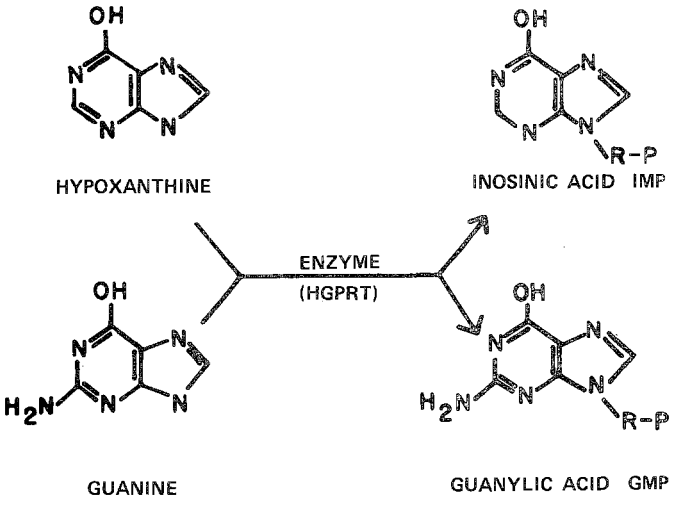
The genetics of this condition are that the transmission is through the female to the male, always in the pattern

of an X-linked recessive character. In studies with Drs. Barbara Migeon and Barton Childs of Johns Hopkins we studied the family of our first patient. The two brothers in the family both have the disease, and obviously the mother is a carrier because she produced them. It has now been shown that she does in fact have cells that carry the abnormal enzyme. We also know now that a female sibling, born after we studied the two boys, also carries the abnormal gene.

What might this girl, when she grows up, do to prevent the continuation of the disease in her progeny? If, in spite of carrying the gene, she is planning a family of her own, it is possible, were she to get pregnant, for us to obtain fluid containing amnion cells from the baby by an amniocentesis, or puncture of her uterus. We could then grow the cells in culture and detect whether or not the baby is carrying the abnormal enzyme. In this condition, and in a number of similar conditions, one can make a prenatal diagnosis of abnormality in time to permit a therapeutic abortion.

If such a woman were willing to go through this business of monitoring pregnancy and the risk of therapeutic abortion, one could guarantee the eventual production of a normal child. This, I think, is a positive approach to this type of problem.

The mechanisms for the neurological and behavioral manifestations of the disease are not known. Experience with patients with, say, phenylketonuria and other metabolic diseases suggests that something with a specific toxicity for the nervous system may accumulate as a result of the metabolic disease. One current operating hypothesis is that the abnormal behavioral characteristics represent the action of some chemical or chemicals that



The enzyme HGPRT ordinarily catalyzes the conversion of the purines hypoxanthine and guanine to their respective nucleotides. In patients with the disease, this enzyme is completely inactive.

What might this girl do, when she grows up, to prevent the continuation of the disease in her progeny?

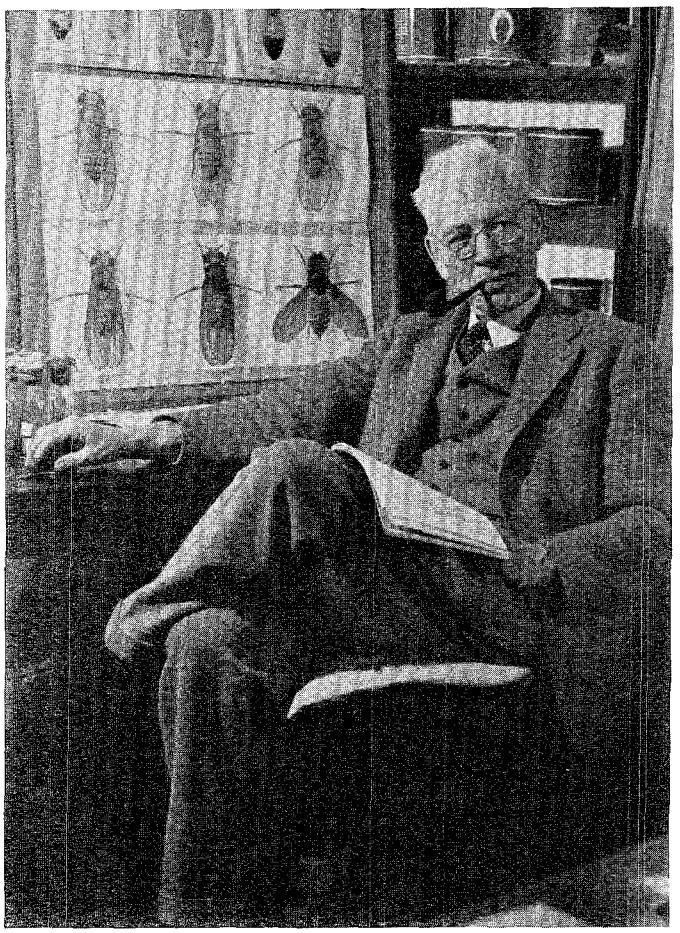
are a consequence of the metabolic defect and particularly of the enormous overproduction of purine. It already appears clear that uric acid itself is not the offending agent. We have been able to control uric acid concentrations quite effectively with allopurinol, which is a superb drug for the treatment of gout. However, it in no way influences the central nervous system manifestations of the disease.

We are now looking at body fluids—cerebrospinal fluid as well as urine—in the search for purines that are different in patients with the disease from those found in control individuals. We have also initiated pharmacologic studies in an attempt to find an experimental model for the behavioral aspects of the syndrome.

The structure of uric acid compares closely with some rather well-known environmental purines, such as trimethyl purine (caffeine) and other methylated purines like theophylline, a drug commonly used in the management of patients with asthma. Both caffeine and theophylline are central nervous system stimulants. Two of our undergraduate students, Jacob Sage and Raymond McConald, have found that rats given large doses of caffeine and theophylline produce self-mutilation of their paws and abdomens. Both of these purines have the 1,3-methylated structure. A third similar purine, theobromine, which doesn't have that structure, produces no effect in the animals.

We settled on theophylline as a type compound with which to compare other chemicals, and we have since experimented with animals other than rats too. One of our most significant results came from a rat, treated with theophylline, who demonstrated self-mutilation worse than any of our patients. Most of the enormous destructive activity was around the mouth, which makes us think this may not be a bad model, and also that it might well reflect the possibility that purines are related to the kinds of abnormal behavior that we have had under study in man.

In conclusion, we have described what might be considered a possible molecular approach to behavior. We have gone from the clinical disease through the metabolic or biochemical abnormality to cell culture studies and enzymology. These studies have the important promise of a chemical understanding of human behavior.



Alfred H. Sturtevant
(1891-1970)

A. H. Sturtevant, Thomas Hunt Morgan Professor of Biology, emeritus, at Caltech, died of cancer on April 5, 1970, in Pasadena. At a memorial service held in the Athenaeum on April 17, Edward Lewis, the current Thomas Hunt Morgan Professor of Biology, paid this tribute to his colleague.

Alfred Henry Sturtevant, born on November 2, 1891, at Jacksonville, Illinois, was the youngest of six children of Alfred Henry and Harriet Evelyn (Morse) Sturtevant. His grandfather, Julian Sturtevant, was a Yale graduate, a Congregational minister, and one of the founders and later president of Illinois College. Sturtevant's father taught mathematics for a while at Illinois College, but for the most part was a farmer, first in Illinois and later in southern Alabama where the family moved when Sturtevant was seven years old. Sturtevant went to a one-room country school, taught by his future sister-in-law, and went to a public high school in Mobile.

At the age of 17 he entered Columbia University. That crucial choice came about because his brother Edgar, who was 20 years older, was at that time teaching at Barnard College. Edgar and his wife took the young Sturtevant into their family, and he lived with them while attending Columbia University. Edgar was a scholar who later became a professor of linguistics at Yale and an authority on Hittite languages. Sturtevant said that he learned the aims and the standards of scholarship and research from him. One can imagine the great source of pleasure it must have been for Sturtevant when he and Edgar were awarded honorary degrees at the same Yale commencement many years later. Also present was Sturtevant's nephew Julian (the son of Edgar) who was at that time and still is a professor of organic chemistry at Yale. Julian Sturtevant's son Bradford, another Yale man, is on the faculty at Caltech in aeronautics, and A. H. Sturtevant's own children are in the same tradition: One son is in anthropology, the other is in engineering, and his daughter is a practicing lawyer specializing in the legal aspects of the use of atomic energy. A student of behavioral genetics might well begin to wonder whether there may not be some influence of the genes as well as of the environment on the academic and scientific performances of this line of Sturtevants.

How Sturtevant became interested in genetics and how he came to work with Thomas Hunt Morgan are especially revealing anecdotes. Sturt, as he was known to his colleagues, has said that he first became interested in genetics by tabulating the pedigrees of his father's horses. He continued this interest while an undergraduate at Columbia, and he also collected considerable data on his own pedigree. Sturt said his brother Edgar suggested that he go to the library and read some books on heredity to learn more about the meaning of pedigrees. Thus it was that Sturtevant read a textbook on Mendelism by the English geneticist Punnett.

Sturtevant saw at once that Mendelism could explain some of the rather complex patterns of inheritance of coat colors in horses which he and others before him had observed. Edgar encouraged Sturtevant to write an account of his findings and take it to T. H. Morgan, who at that time was a professor at Columbia and from whom Sturtevant had already taken a course in zoology during his

freshman year. Morgan encouraged Sturtevant to publish the paper, and it was submitted to the *Biological Bulletin* in June 1910, at the end of his sophomore year. The paper appeared that same year.

The other result of Sturtevant's interest in the pedigrees of horses was that he was given a desk in the famous fly room at Columbia University where only three months before Morgan had found the first white-eyed fly, a discovery that was to revolutionize genetics. Much of the rest of the story about those early days at Columbia, when modern genetics was in a very real sense born, is a matter of record in the writings of Sturtevant and others.

Sturtevant had a keen interest in the history of science; his book, *The History of Genetics*, which was published in 1965, bears witness to this. This book contains a typical example of the workings of Sturtevant's mind. In it he compiled an appendix that contained a series of "intellectual" pedigrees of many of the men prominent in genetics or cytology in the early days. Sturtevant, of course, was a direct descendant of T. H. Morgan and of E. B. Wilson, another eminent biologist who was a contemporary and friend of Morgan's at Columbia and who was at that time the authority in this country on the cytological behavior of chromosomes and the cell itself. Morgan and Wilson were, in turn, direct descendants of Martin and Brooks, two men who were at Johns Hopkins University where Morgan had obtained his doctorate; Martin was descended from T. H. Huxley, and Brooks from Louis Agassiz, and so it went.

From Morgan, Sturtevant must have first learned—or at least seen in operation—the experimental approach. Sturtevant once wrote that he knew of no one else at the time who was so thoroughly committed to the experimental approach to biological problems as was Morgan. It was Morgan's aim to produce a mechanistic, as opposed to a purposeful, interpretation of biological phenomena; a great deal of this approach clearly rubbed off on Sturtevant, for the simplistic elegance of Sturtevant's experiments in genetics are legendary.

Sturtevant had a remarkable memory of, I suspect, a special sort. It was as if his memory were composed of an infinity of matrices waiting to be filled with any data that lent itself to classification into discrete categories. The data might be in the form of numbers and kinds of bristles missing in a mutant fly; numbers of snails with a right-handed coil versus a left-handed coil—the genetics of which Sturtevant was the first to explain; the relation between inversion sequences in different species; or the host of other characteristics he investigated not only in *Drosophila*, but in iris, evening primroses, snails, moths, and many other creatures, including human beings. Whatever form the data took, the observations fell in the appropriate matrix in his memory, from which they were readily retrievable to a degree that was truly phenomenal.

The Caltech period was a time of collaboration especially with Sterling Emerson, Theodosius Dobzhansky, George Beadle, Jack Schultz, Edward Novitski, and others. It was Sturtevant's style, at least after he came to Caltech in 1928 with Morgan and Bridges, to spend his mornings doing experiments. Afternoons were reserved for perusing the literature—and there were few journals in any phase of biology that he did not at least dip into—and there were the wide-ranging discussions at the afternoon tea sessions.

Sturtevant taught the undergraduate course in genetics at Caltech for many years. From time to time he also gave a course for undergraduates in entomology, complete with a field laboratory session. His lectures on topics in advanced genetics were scholarly reviews of specialized areas of genetics—often dealing with organisms with a bizarre genetics, such as the protozoa, for example. These lectures were especially valuable to graduate students since they were in areas of research not directly going on at Caltech, and they served to broaden their genetic outlook. The elementary course in genetics that Sturtevant taught was based on a textbook which he and George Beadle wrote in 1939. It was not as widely used throughout the U.S. as it perhaps should have been, probably because it was considered too difficult for the average student. The trouble was that it was tailored for Caltech students, and the problems especially were a real challenge, even for Caltech undergraduates.

Sturtevant and Beadle planned to revise the textbook, but the pressure of other work and the rapidity of developments that followed the discovery of DNA prevented that revision. I would like to mention one episode in this regard. There is a subtle difference in the way geneticists use the word *gene*. Sturtevant discovered that he and Beadle had in fact used the word differently when they wrote the book, and he always facetiously blamed their inability to get out a second edition on this disagreement. Characteristically, when he became aware of this ambiguity in the usage of gene, he would ask every geneticist he met how he used the term, and he then promptly cataloged his colleagues according to whether they thought of the gene the way he did or the way Beadle did. The person asked did not, of course, need to worry about his answer because he would be sure to be in good company in either case.

Sturtevant read widely and was extremely well informed on every topic of current interest, especially politics. He would, for example, read the Sunday *New York Times* and the *Manchester Guardian Weekly* from cover to cover. He was especially happy if he could do the crossword puzzle in the *Guardian* at one sitting. Those who know those puzzles will know that only a very special breed of person attempts them, let alone solves them in one sitting. Sturtevant was fascinated with puzzles of all

kinds—especially puzzles involving three-dimensional objects. When Anne Roe made a study some years ago of what makes scientists tick *(The Making of a Scientist),* she wisely chose Sturtevant as one of her subjects. He was not only flattered, but overjoyed at the opportunity to take the tests, which he viewed as simply a new set of puzzles to work out.

Sturtevant would develop a topic logically and succinctly, whether he was publishing a paper or giving a formal lecture. In private conversation, however, he always seemed to assume that the listener was at least as well versed in the subject matter as he was, so he'd leave out the preliminaries and get right to the point. This could be mystifying to some; for others it was a challenge to become versed enough to profit by listening to his ideas or by tapping the tremendous store of information always at his fingertips on almost any topic of substance. His papers were so well written that one would assume that he had labored over each word. I have seen his pencilled manuscripts; they rarely contained more than a few minor word changes inserted into the original draft, which was always done in longhand. I once asked him how he did this; he told me that he usually spent many days mulling the paper over in his mind until all the words fell into place, and then all he had to do was write it down from memory.

Sturtevant's colleagues and students and friends at Caltech will always remember the warmth of his personality. His love for people and for all living things was expressed in many ways. For example, in 1954 he gave the presidential address before the Pacific Division of the American Association for the Advancement of Science, and he dealt with some of the social implications of human genetics. In this address he warned of the hazards to human beings of the fallout from the atmospheric testing of atomic bombs. What had provoked Sturtevant was a strong statement issued by the executive branch of the government that the fallout levels from testing were far below any that could cause damage to human beings.

Although many assumed that the only purpose of Sturtevant's remarks was to halt bomb-testing, he was completely objective about the whole problem. He felt there might be a need for bomb-testing but that the public should be given the best estimate that scientists could make about the nature of the danger of fallout levels of radiation to the unborn. To use the language of today (some 16 years later), Sturtevant was decrying the credibility gap that was developing in the government's handling of information on environmental pollution with radiation.

For Sturtevant, life must have been an exciting, rewarding, and perhaps sometimes heartbreaking journey into the unknown. It was fortunately a long journey, which involved many detours to many realms, and I am convinced that he savored every minute of it. His explorations in genetics will make the journey into the unknown a little easier for the human race.

Books: A Double Review

The Coming of the Golden Age: A View of the End of Progress

by Gunther S. Stent
The Natural History Press, Garden City, New York.....$4.95

Reviewed by Richard E. Dickerson
Professor of physical chemistry

Gunther Stent's *The Coming of the Golden Age: A View of the End of Progress* is really two independent books between one set of covers. The first four chapters, entitled "The Rise and Fall of Molecular Genetics," are a personalized view of a field of science in which Stent has been an important participant. He divides its history into a Classic Period, during which a gene was an abstract concept rather than a molecule; a Romantic Period, when even physicists speculated that the laws of chemistry and physics might be insufficient to account for the gene; a Dogmatic Period dating from the Watson-Crick DNA double helix; and the current Academic Period in which molecular genetics has become both respectable and dull, and the romantics have moved on to look for new frontiers. Stent views himself as a frustrated romantic who has lately realized that the number of new frontiers is strictly limited. As with Watson's *Double Helix*, I enjoyed these chapters and learned from them. Whether what I learned was correct in nuance as well as in fact, I leave to more competent judges.

The last three chapters, "The Rise and Fall of Faustian Man," are the real heart of the book. They are an elegy for the decline of progress, and for Faustian man, who is its architect. Adopting the imagery of Oswald Spengler and Friedrich Nietzsche, Stent sees Faustian man as having a driving "will to power," or the desire to manipulate the external world successfully for his own ends. Such a man, in Stent's vision, is the hero of the drama of history.

In complete contrast to Faustian man stand the beat generation of a few years ago and the present hippie movement. Seen in a narrow sense, Stent's book is

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Reviewed by Max Delbruck
Professor of biology

"A new age is dawning: everybody seems to have noticed it . . . I consecrate my essay to the Golden Age whose onset *I* happen to envisage . . . The arts and sciences will have reached the end of their long road."

The first part of this book details the history of molecular genetics, a field in which the author is a professional. Here his account is as knowledgeable and incisive as any that could be written today. It is lively and untechnical. A defect perhaps is its overemphasis of the fascination with the paradox claimed to have obsessed the members of the early phage group. I do not think that any member of that group *believed* that new laws of physics would be discovered in the unraveling of the riddles of genetics. Only a few of them were even motivated by contemplating such an outcome as an intriguing possibility. Otherwise, the characterization of the four periods (the Classic, the Romantic, the Dogmatic, and the Academic) appears to me germane to the subject, and witty, especially a picture of the Nobel ceremony in 1962 with the caption "Solemn Inauguration of the Academic Period."

Stent's comments on the great remaining paradox of biology, the relation of mind to matter, are as intelligent and as unsatisfactory as any that I have read. And no wonder. Where everybody else, including Niels Bohr, fails, why should not he, too, fail to enlighten us? It is important, though, to remain disquieted by this problem.

The second part of the book, entitled "The Rise and Fall of Faustian Man," is much more fascinating to me and probably to most readers. The author asserts that universal progress is a parameter of human society which can be at least crudely measured; that it has been accelerating over many millennia; that its occurrence had not been noticed, and that therefore the concept of progress had not been formed till about 200 years ago when the rate of progress became sufficiently fast to become a matter of personal experience during a lifetime; that, considering the psychic and material dynamics involved, there must be some upper limit to progress; and that this upper limit will be approached within a few decades. These points are presented persuasively and I, for one, am not inclined to contest them.

What follows? In the view of the author there follows, and is near at hand, the end of the arts and sciences. In the arts this end is clearly discernible by the constant acceleration of the rate of change of styles and their progressive lack of semantic function, tending to the extreme in which sense experiences are considered the only truths and the

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In 1948 Gunther Stent, who had just finished his graduate work at the University of Illinois, arrived at Caltech as a research fellow in biology. He joined the Institute's Phage Group, organized only a year earlier to work under the direction of Caltech biologist Max Delbruck. Stent left Caltech in 1950 to do research in Copenhagen and Paris, and in 1952 went to the University of California at Berkeley, where he is now a professor of molecular biology and of bacteriology.

Books

Delbruck . . . *continued*

function of the artist consists solely in adding to the store of unique experiences. In science, Stent asserts that the vanquishing of all threats to human survival (hunger, cold, and disease) will make further scientific research ever decreasingly useful. He considers that chemistry and biology have now, or will soon have, no deep problems left; that physics, though it is open-ended, is limited in practice because of expense and feasibility and because it is becoming progressively less clear what it actually is that one is ultimately trying to find out; that mathematics is open-ended ever since Gödel's theorem, but that one may doubt whether the human brain was designed by evolution to handle the problems of future mathematics. On the whole he believes that with further abstraction there will occur a loss of psychic meaning of the insights gained and hence a weakening of the intensity of interest in probing further.

What follows? In the view of the author there follows, if we are lucky enough to avoid war, the Golden Age—a brave new world clearly heralded by beat philosophy and hippie movement, somewhat similar to the Polynesian culture, a race without will to power, without Faustian aspirations, free from toil and grief and with a great deal of synthetic happiness, a culture involving erosion of the reality principle and with an autistic feeling of oneness with the universe. "Millennia of doing arts and sciences will finally transform the tragicomedy of life into a happening."

A book of this kind, to bolster its vision, must necessarily be very sweeping in its generalizations and extrapolations. Thus, the Berkeley scene is taken to stand for student unrest the world over, and U.S. affluence is assumed to spread across the globe in rather short order. However, I do not wish to criticize details. I think it is a bold and important book. I think it should and will be read by many people, young and old. I think it should be discussed on the basis of reading it rather than upon reading a review of it. And I think more people with encompassing interests who have thought seriously about human affairs should write their books regarding the coming ages.

Dickerson . . . *continued*

a diatribe against the hippie culture that has sprung up outside his laboratory. But Stent views the hippies, with great regret, as the wave of the future, which he ironically calls the "Golden Age." The outright rejection of the accumulation of goods as ends in themselves, a withdrawal from the world rather than the successful manipulation of it, and a turning away from the exercise of power —all are signs of the decay of Faustian man, and the onset of what Stent calls in his final chapter "The Road to Polynesia."

Progress, according to Stent, is self-limiting and contains a negative feedback that insures its own demise. The will to power thrives in times of adversity, for "the higher the degree of economic insecurity extant, the greater the power over external events needed by the individual for his survival." But the successes achieved by Faustian man make it less probable that he will transmit his will to power to his descendants. As Stent says:

> In Western society, a decline of Faustian man set in the nineteenth century, mainly brought about by the economic fruits of the Industrial Revolution and the social consequences of the rise of liberal democracies in Europe and America. The ever-mounting degree of security provided to the citizens of bourgeois societies then began a gradual erosion of the intensity with which the environment of child rearing engendered the will to power in the adult.

Progress, which began before the rise of civilization, and which has been accelerating at an exponential rate since the beginning of the Industrial Revolution, will soon level off and stop, principally because it has succeeded so well that it has sapped the will to continue. The few Faustian men left (and Stent rejoices that he will not be one of them) will provide the minimal effort to keep the wheels of the economy turning so that the masses can spend their lives on one long trip.

In an essay criticizing Arnold Toynbee, the Dutch historian Pieter Geyl compares history to a thick bouillabaisse, full of all manner of things, from which each historian dips what he needs. Toynbee, says Geyl, so astonishes you with what he produces that you never notice what is left behind in the cauldron. Stent's argument is subject to the same criticism, for Stent totally overlooks the one time in human history when a revolution of comparable magnitude to our present Industrial-Technical-Scientific Revolution took place. This was the Neolithic Revolution, which occurred in the Middle East around 9000 B.C. Before that time, *Homo sapiens* lived in small roving bands of hunters and gatherers. After the discovery of agriculture and the domestication of animals, the economic basis of human life became farming, and remained so for over 10,000 years. Both the Neolithic and the Scientific Revolutions produced (or are producing) massive changes in the pattern of life for all of mankind. In contrast, the changes in life style between these two revolutions have been confined to a minority of the population. As late as 1700, the great majority of the human species, even in Europe, was still living a peasant farming existence that would not have seemed strange to an early neolithic farmer. All of the wonders of urban, literate civilization rested on a technical and economic base which had changed little in ten millennia.

Perhaps the idea of "progress," which Stent claims has been used only during our latter-day Scientific Revolution of the past 200 years, is in reality only applicable during the explosive growth of such transition periods. After the first spectrum of domesticated plants and animals, farm technology stabilized. Relatively few *new* species were domesticated between the Neolithic Revolution and the Scientific, and improvements in technology were largely limited to finding better ways of turning the soil over by animal power. If a neolithic Farm Bureau agent were to define progress as an increasing mastery over new species of plants and animals, then he would have to admit that progress quickly came to a halt after the initial rapid successes with various grasses, beans, gourds, dog, cat, sheep, goat, cow, water buffalo, elephant, llama, duck, chicken, pigeon, cormorant, onager, and horse. (The camel represents much later

progress.) Perhaps in a few centuries, when our own revolution can be seen in perspective, our current criteria of progress will appear as provincial as those of our neolithic stockbreeder.

If I were a satirist, I could write the chronicle of a pre-neolithic scholar of hunting, who devoted his life to a study of the habits of the species on whom he depended for his existence (called, perhaps, Nimrodean man after Nimrod the hunter, Noah's great-grandson), and who gloried in the heroism of the chase. But as his quest succeeds, and his understanding of his quarry reaches completion, he becomes dismayed to see other people accept his findings without using them as he had intended. Instead of cultivating the noble virtues of Nimrodean man, and inculcating the will to hunt in their offspring, these degenerates pen their onetime prey in ignominious captivity, slaughtering them without personal danger when the need arises. Instead of exercising the intelligence and initiative needed to track down edible plants, they first destroy the natural ecology, and then strew seed about, to be collected later in relative idleness. Woe to the coming generations, our prophet cries, when the will to hunt is gone. Nimrodean man is no more, and the children of the new affluence waste their newfound leisure in self-gratification and in withdrawal from the world of reality!

Of course, no such thing occurred. The Neolithic Revolution *did* bring economic affluence. Rather than each man having a full-time struggle for bare subsistence, one man or one family could produce enough to keep many people alive. But this economic surplus was not frittered away in sedentary navel-gazing. The surplus that each farmer accumulated enabled him to bargain for things that he could not produce (and *therefore formerly had to do without*). This in turn made it possible for other people to exist without farming; by making what others wanted and would bargain for. The full-time professional artisan arose, and the roots of technology began. From this economic surplus came urban, literate civilization, and all the advantages that are customarily ascribed to it.

Participants in a movement are poor prophets. The art of writing would have seemed of marginal use to our imagined frustrated scholar of hunting. Metallurgy and better weapons he would have appreciated, but he would never have seen how they could be developed in a hunting culture in which time off from the hunt today meant potential starvation tomorrow. One might as well try to go to the moon.

Stent sees the hippie movement, with a loss of the will to control the environment, as the inevitable response to a release from economic pressures. We are certainly being freed from such pressures, in a way that has not been so dramatic since we first learned to grow crops and keep cattle. But Stent's view of what we will do with our new leisure is open to serious challenge. There were probably a few converted hunters in 9000 B.C. who were content to scratch the soil, harvest the crop, and spend the rest of their time in a hammock. Such marginal cultures exist today, and they might fairly be called the descendants of the hippies of the Neolithic Revolution. But the bulk of mankind did not make this response. Stent's prime difficulty is that he cannot see, or cannot even imagine, what *Homo sapiens* might do with the new freedom following the eventual working-out of the Scientific Revolution.

I cannot believe that Faustian man is merely the product of economic determinism. I prefer to believe that *Homo sapiens* is curious in an intelligent way because intelligence and curiosity have a high survival value for the species, and always have had, and that the process of natural selection has favored those groups and societies that have fostered curiosity, intelligence, and initiative. Someone from our time might say to our disgruntled neolithic scholar: "*If the hunt has developed the highest* qualities of man, think how those qualities could grow and flourish if man were relieved of the necessity of fighting every day for survival." And today, we can say to Stent: "If Faustian man has achieved so much in a world of strictly limited energy sources and unknown forces, what might he not attain if these limits were removed?" People often cannot see the challenge of new circumstances. Stent himself makes the very perceptive observations that the idea of progress arises only when changes in life style begin to occur so rapidly that they can be noticed in the span of a single generation, and furthermore that alienation and withdrawal occur when this change becomes too rapid to be adjusted to and accepted in a single lifetime. He meant his comments to apply to the beats and hippies, but like so many of our comments, they tell us as much about the speaker as the subject.

To buttress his case for the decline of progress, Stent devotes one chapter to "The End of the Arts and Sciences." Here he argues that there has been a steady and progressive loosening of the rules of style and composition from ancient times in music, art, drama, and architecture until we have now reached such absolute formlessness and anarchy that no further change is possible. It is tempting to the ego of the reviewer to embark on a detailed analysis of his arguments, but space forbids this. Stent does not like modern art, modern music (which he equates with Schönberg and John Cage; jazz and the return to modal harmonies of current rock music are ignored), modern drama (which he equates with the theater of the absurd), or modern architecture; and he generalizes this personal dislike into a statement of the current meaninglessness of the arts. In science, he manages to have it both ways simultaneously: Chemistry and biology are at a dead end because their subject matter is finite; physics is at a dead end because its subject matter is infinite. And at least in the discussion of the history of music, the bouillabaisse syndrome is much in evidence. This chapter is totally unconvincing, and hence weakens the edifice built up in the *previous and subsequent chapters.*

This book is highly recommended to those who love a good fight, or who read a book with red pencil in hand. One only wishes for wider margins. It would be an admirable focus for a graduate or undergraduate discussion group, and is to be commended for its clear and enjoyable style. But whatever else you do, do not take it as gospel.

They seem as able to detect minimal painful stimuli as are subjects of other races; however, their ability to disregard the painful stimuli almost completely is remarkable.

mountainside several times a day. A wiry habitus (build) with little subcutaneous tissue, thin skinfolds, and easily visible ribs, with no excess fatty tissue, may well provide an ideal low-weight frame for such high load-to-body weight ratios. Perhaps this habitus is well adapted to the high work requirements with concomitant scarcity of protein-rich foods. In this connection we have observed that schoolboys and young laborers going off to work on coastal plantations have rapidly changed their habitus in less than a year on enriched diets containing rice and ample fish and meat. The change is such that they are hardly recognizable any longer, even to their kinsmen. Such youths returning later to their homeland and no longer receiving the enriched diet are noticeably unfit for the rigors of hunting and the primitive subsistence farming. Their load-to-body weight ratios are much lower than that of their "undernourished" kinsmen, and their high requirement for water on the parched, grass-covered waterless mountain slopes produces an added physical burden. Since the community cannot sustain that high level of protein intake for them, their efficiency and health often fail rapidly back in their homeland.

Summarizing some of the adaptations that have occurred: delayed growth and maturation, short adult stature and low weight, reduction in metabolic rates, lower water intake and urine volume, and decreased sweating and sweat sodium content and, surprisingly, a high level of physical fitness. There is an increased proportion of nitrogen excreted in the feces, increased hippuric acid excretion, decreased urinary amino acid excretion, increased serum gamma globulin, and lower levels of serum cholesterol and lower blood pressure in adult life.

Deformation, Mutilation, and Scarification

The practices of mutilation and deformation are encountered in contemporary primitive peoples, and the historical record carries them far back through the civilized cultures of Europe and Asia, and the archaeological and paleontological record extends these practices into man's distant past. They are present on all continents and in all races of man, and they fill needs that are common to all mankind, usually that of adornment and its signal role in sexual attraction, but at times more as a symbolic need as well. The ascribed motives for mutilation and deformation are usually aesthetic or magical, but they are also performed in the nature of a sacrifice, as the removal of fingers from children and adults as a mourning rite for their deceased relatives. Healing of injuries or illness is a common reason. At times the practice is performed for ascetic mortification, as in initiation mutilations. In many Melanesians, and certain aboriginal groups in Australia, we still have an opportunity to see a wide range of these practices.

Cranial Deformation from Headbinding of Infants

Although headbinding and other artificial cranial deformations of infants for magical or cosmetic purposes have been described over the centuries, the actual practice has virtually disappeared from the world in the past few decades. Thus, the possibility of examining infants with these severe cranial deformations, and observing their neuromuscular growth and intellectual development, is all but gone. In 1956 and again in 1960, I noted that the practice was still universally employed in a few villages in the central mountain ranges of New Britain among the Mamusi and Mangsing peoples. The coastal Arawe people in southwestern New Britain, who were previously known to value a markedly elongated cranium and backward sloping forehead, and who also achieved this by tight circumferential binding of the head with bark cloth, have

The extensive keloids on the shoulders and back of this Waragu warrior of the Great Papuan Plateau are the result of burns inflicted when the youths of his longhouse have gone to dance at a neighboring longhouse. The women of the host village thrust burning brands at the visitors during their frenzied dance.

not abandoned the practice. Other New Britain groups, like the West Nakanai, had already abandoned the practice almost a century ago.

Deformation of the skull can only be accomplished by compression during infancy. The process is, therefore, dependent upon the foresight of the parents who desire to endow their child with the head shape which is fashionable in their group. The deformation has been accomplished in various people by the use of bandages, boards, and tightly fitted caps and headdresses. It has been practiced in many parts of the world, especially by various American Indian tribes, the Milanau of Borneo, the natives of Malekula in the New Hebrides, the Mayogo and Mangbetu in the Congo in Africa, and until recently, even in parts of Europe. In ancient Peruvian mummies similar artificial cranial deformation is observable, and drawings in Aztec manuscripts illustrate the results of the practice.

Response to Pain

Melanesian groups provide us with a further physiological and psychological pattern of failure of response to pain which is both unusual and somewhat baffling. The juxtaposition of current-day Melanesian peoples who still demonstrate an incredible tolerance to painful stimuli, with hypersensitive, almost hypochondriacal Polynesian groups, provides a natural laboratory for assessing the phenomenon.

It is not unusual to find small children or toddlers submitting voluntarily to scarification procedures or burning to produce keloids, which are performed purely for cosmetic purposes or as healing rites. Children from five to 12 years of age often sit together in groups, burning themselves or each other with the tip of a burning stick taken from the fire, to make circular, third-degree burns up and down their arms and forearms. These later fester and heal to produce the desired keloids. The unwincing toleration of these voluntary, often self-inflicted, burns is remarkable. At times, the smell of burning flesh has first made me aware that children in my house were engaged in this activity.

Many Highland groups, such as the Fore and Gimi, practice self-amputation of fingers as a mourning rite at the death of relatives. Most adult women are missing two or more fingers from their left hand and often as many from their right. Small girls, related to the deceased, submit without crying to the procedure. It is usually done by the tight binding at the first or second interphalangeal joint with a cord, pulled so tightly that the distal phalanges become gangrenous and slowly drop off. In some instances the finger is quickly cut off with a knife or axe.

Few children of the northern Auyu peoples are lacking a large series of circular burn scars, one to two centimeters in diameter, over their precordial region and upper chest anteriorally. Many also have similar burns on their shoulders and on their cheeks. The latter are produced to relieve severe toothache, often in childhood. The shoulder burns are produced for generalized illnesses, and the chest burns for illnesses involving cough.

Among the Waragu and other Bosavi peoples of Great Papuan Plateau most late-adolescent youths and men have extensive, huge keloid burn scars over their backs and shoulders. These are produced during frenzied dancing when dance teams of youths visit neighboring, usually enemy, longhouses during brief periods of truce to dance all night for their hosts. During these visits they receive hospitality which includes the thrusting of flaming bands on the dancers' shoulders. Extensive, sometimes fatal, third-degree burns are produced without interruption of dancing.

Among the Awa people of the Eastern Highlands, young teen-aged boys submit to continued snapping of a bamboo rod against their upper arms by the young girls during courting, to produce slash-like traumatized lesions which undergo necrosis and inflammation and eventually keloid formation.

Asmat men and women produce both with bamboo knives and with burning an extensive, highly controlled decorative keloid scarring of well-executed traditional designs.

Frequently, when the Melanesian men and youths are carrying our supplies over mountain ranges in the New Guinea jungles, we have found that a single carrier may assume the load of two or more carriers, fastening it over his shoulders with vines, instead of using the pack frames. While trudging behind my carriers, I have only belatedly been aware of their injury on finding blood along the trail; and later, on overtaking the carriers, I have found that one or more have cut the skin over their shoulders and clavicle through to the bone without bothering to stop to place pads under the vines or change to a pack frame.

Many other stories of similar obliviousness to the painful injuries on the trail could be cited. One might presume that these accounts related to incredible feats of endurance. However, when one realizes that they are already experienced by young children, often voluntarily, this becomes more remarkable. On the other hand, the civilized observer, attaching vast import to the pain inflicted, may often be surprised by the reply from the victims that "it does not hurt very much," accompanied by laughter or a smile.

In the hospitals in the outer regions of Melanesia, where both Polynesian patients from the Polynesian outlying islands in Melanesia are attended together with Melanesian patients, the contrast between the responses of the two groups to pain and suffering from injury or other illness is amazing. Melanesians, but not Polynesians, with severe fractures, lacerations, or burns suffer and undergo painful procedures without complaint, often themselves testing their fractures for crepitus. Similarly, the excruciatingly painful disease of tropical multiple pyomyositis, of presumed filarial origin, which occurs frequently among both races on these islands, produces

comparable excruciatingly painful and tender swelling with much less disability and complaint from the Melanesian than from the Polynesian patients. In other diseases, such as advanced pulmonary tuberculosis, the disparity of behavior between the two races is equally remarkable, with nearly moribund Melanesian patients still seeking to remain ambulatory and at work, and less severely ill Polynesian patients long since having become completely bedridden.

We have no evidence of increased pain perception threshold in the Melanesians. They seem as able to detect minimal painful stimuli as are subjects of other races; however, their ability to disregard the painful stimuli almost completely while they are engaged in other activity is remarkable.

Elisabeth Beck, of the Neuropathological Service of the Maudsley Hospital in London, and I have found unexpected variations in fine structures of the brain in Melanesians, including the size and shape of the septal nuclei, massa intermedia, thalamic and hypothalamic nuclei, lateral geniculate bodies, and the frontal lobes. Neuroanatomical detail may vary with individual and group as do facies, hair, and habitus. The awareness or response to intractable pain in cancer patients has been dulled in man by stimulation of the septal nuclear area by R. G. Heath. It is tempting to wonder whether neuroanatomical differences in this area in Melanesians might not permit their less exaggerated response to pain.

Penile Display

Limbic Neurology

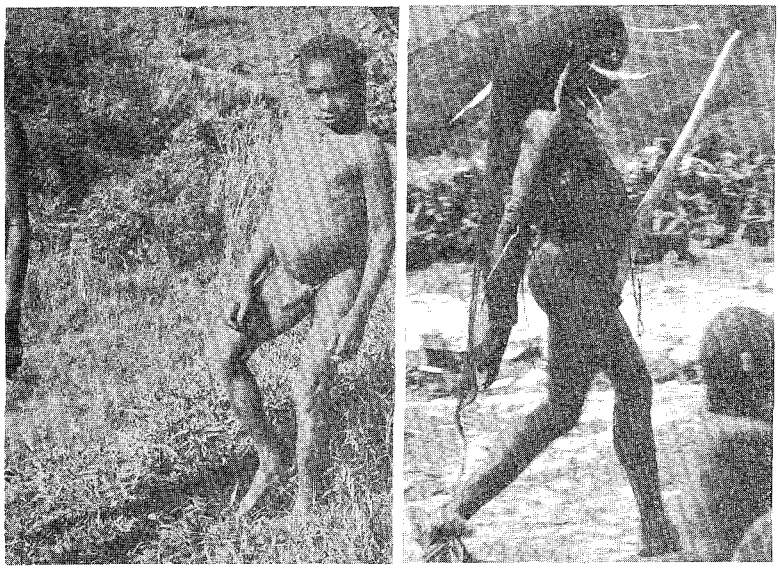
The paleocortex, the rhinencephalon or smell brain of older literature, has emerged in the newer neurophysiology as the seat of integrative activity involving our emotions. It lies between our "reptilian" brain or brain stem, and the neomammalian cortex. It is this paleomammalian brain, the brain of our tiger or horse between our crocodilian brain and our human cortex, as Paul MacLean, Director of the Laboratory of Limbic Integration and Behavior of the National Institutes of Health, has put it, which controls the mobilization of emotional responses for self-preservation and for the preservation of the species.

Close neural relationship accounts for the spillover of electrical excitation in one part of the limbic system into another part. This limbic neurophysiology explains the interplay of primitive oral and sexual behavior as well as their connection, at times, with agonistic behavior. Thus kissing in lovemaking, feeding with associated penile erection in babies and animals, and sexual excitement of pyromania that is aroused by fear-inducing fires, and sadism and masochism are all more easily understood.

The display behavior of the Gothic variety of the squirrel monkey *(Saimiri sciureus)* in presenting an erect phallus when responding to another monkey in situations of courting, aggressive challenge, or dominance, or from a distance as a greeting, involves a patterned behavior of

vocalization followed successively by thigh spreading, penile erection, scratching, and some urination. The animal also performs this patterned display response when confronted with its own image in a mirror. In a group, the displaying animal makes a forward encounter with a female or another male, spreads the thighs, and thrusts the erect phallus toward the face of the other animal. Display to the female presumably serves as a signal in courtship behavior, as it precedes attempts at copulation. In the case of two males, however, it appears to be primarily an aggressive act because it occurs in exerting and establishing dominance. If the recipient does not remain quiet and submissive during the display, it may be viciously assaulted. When performed at a distance between two or more animals, the display seems to serve as a greeting, as is the display evoked by the animal's own image in a mirror, or it serves as a social signal of appeasement, employed by the dominant intruder to diminish the fleeing or avoidance of the excited group. A reflection of only one eye can trigger the mirror display, but not the reflection of an extremity, tail, or trunk. The display reaction has been used to investigate the cerebral localization and neural mechanisms of visually guided sociosexual behavior.

I have noted a quite similar presentation and display in both spontaneous and socially ritualized behavior in some New Guinea groups. It is similarly used to express both aggression and dominance, in the form of a distant greeting or appeasement, in obviously erotic dancing, and also as a spontaneous expression of anxiety, joy, or elation. This is particularly obvious among the Asmat and Auyu-related peoples of southern New Guinea. When frightened excited, elated, or surprised, groups of Asmat men and boys spontaneously meet the precipitating event by a penile display dance, which involves much the same sequence as the presentation display of the squirrel



The phallocrypt is the traditional dress of over a million people in the highlands of New Guinea. It appears to be a flamboyant extension of the use of smaller gourds and other display ornaments worn by lowland peoples. Within the prescribed form of attire is ample room for individual preference. At times this genital boasting (under the guise of genital concealment and prudish modesty) may reach such extremes as to interfere with binocular vision, as in the figure on the right.

monkey. This behavior is performed on the arrival of strange visitors, on the departure of strangers who have been received with friendship, or in response to excitement or anxiety-producing events, such as the burning of a house, victory in fighting, a severe thunderstorm, completion of a communal effort involving exertion. In more formalized ritual form, the vocalization, thigh spreading, genital grasping and rubbing, erection and pelvic thrusting behavior pattern has been introduced into the traditional night dance of the Asmat and Auyu peoples, which at times may become even more overtly erotic and copulatory.

The males of these and surrounding groups on the coastal plain wear no genital covering at all. In the cultures further inland, however, the males have adopted a less active and more continuous genital display with the male attire consisting of a wide array of prominent penis coverings: nuts or shells, or braided sheaths or gourds; the beak of the hornbill has been used by many groups for this purpose. In most of the Highland cultures of western and central New Guinea, this phallocrypt has become an enormously elongated gourd. To the north of the central ranges, in the Sepik headwaters, the penile covering has been replaced by a baseball-sized spherical gourd, worn only over the distal part of the penis. The ritual dance of the Waina-Suwanda peoples leaves no ambiguity, explicitly emphasizing the display nature of the performance. Thus, for the purpose of the dance, the usual glans penis-covering gourd is replaced by a much larger and longer gourd, which throughout the dance is flipped from between the legs up against the abdominal wall by undulating movements of the thighs and pelvis.

We have, thus, a full complex of genital display performances which, at their extremes, are closely similar patterns to the display performance of the squirrel monkey, the neurointegrative mechanisms of which are

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How great is the leap from Stone Age Man to our modern civilization?

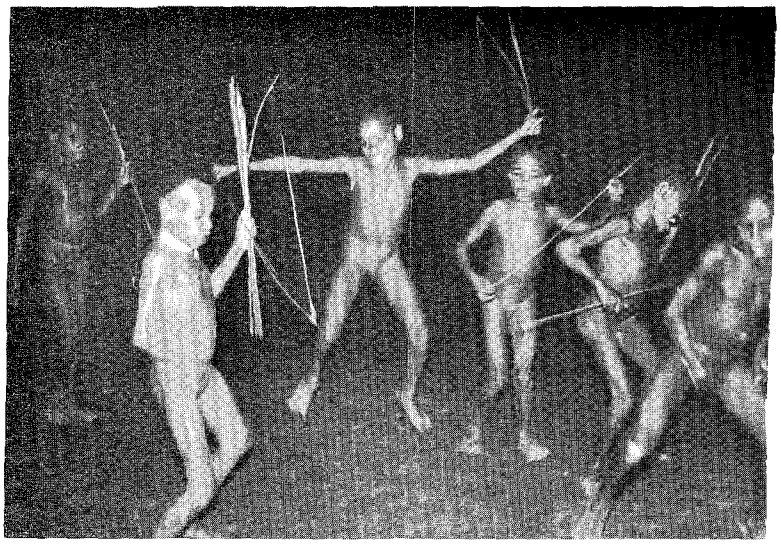
today well understood. MacLean has noted that while Old World monkeys and also pygmy marmosets use a rear-end presentation, or anal-perineal region display in courting and aggression, and while these New World squirrel monkeys use phallic erection and pubic display and thrusting for the same purposes, the white-lipped marmoset instead uses the protrusion and phallus-like elevation of his tongue for these purposes. Here displacement has occurred in the body part employed for the same signaling purposes. On the other hand, with the patterned phallic displays, an integrated genital or courting response appears to have been displaced to serve other social functions.

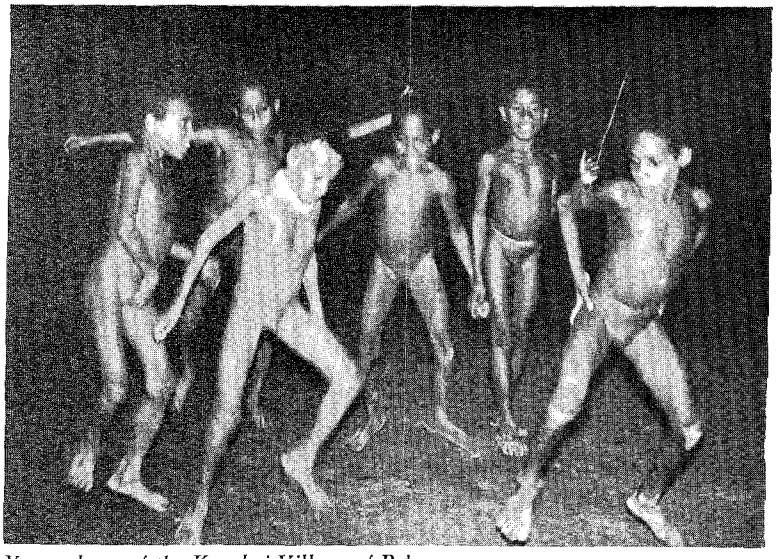
Exhibitionism has its concomitant signs of physical arousal everywhere, and every pediatrician is aware of the erection in small boys that often accompanies their being undressed. Needless to say, our own cultures have not failed in the elaboration of this basic biological pattern; one need only be reminded of the prominent cod pieces of male attire of only a few centuries ago and the dances of the past decade. Our own slang of aggression contains many threats of anal and genital presentation and assault, as do our aggressive gestures, and the sticking out of the tongue is not unlike that of the white-lipped marmoset.

We thus have, in this genitalia display response, a behavioral pattern—gestalt of behavior, if you will—which belongs to the behavioral repertoire of primates. It appears in slightly modified form in different primates, and in different cultures of man it has been variously modified, emphasized, or suppressed. It originally had an easily recognized purpose in the monkey, fulfilling directly a basic reproductive function; as with most sexual signals it has also been used in aggression.

In human groups the goal to which this response complex is directed, however, has been easily shifted in the process of cultural improvisation. In the diverse cultures spread over the complex terrain of New Guinea, we can see a great variety of modifications of the form of display reactions, with emphasis and deemphasis of certain elements of the behavioral complex, and at times slight, and at other times great, displacement of the original biological aim.

Thus, genital presentation and display have been displaced from their primary goal of courting and coupling to an expression of aggression, to an anxiety-quelling behavior complex, to ritualized dance, and to ceremonial greeting, appeasement, or rejoicing. The kinetic, active patterns of response have been abstracted to a less dynamic form in penis-emphasizing sheaths, nuts, shells and, finally,





Young boys of the Kombai Village of Be'a on the Upper Mappi River of West New Guinea dance at night with the genital display and presentation traditional of the peoples of the area.

into a static symbol for the whole rite, in the wearing of long phallocrypts. In the group most disguising the whole pattern of genital display, the Anga, who modestly hide their genitalia under two or three dozen grass sporans, wear so many sporans that they produce a phallic-like anterior projection from the body wall of the piled sporans themselves. In their dance they jump about, with their feet slightly spread, so as to flip their voluminous skirts up and down. In its most exuberant climax they do this in such a way that the heavy pile of sporans flaps against their abdominal wall and exposes their genitals. This is accompanied by copulatory rhythm chants and with a whoop at climax. Thus, even with an ostentatious gesture to mute and disguise the whole response, they finally return to it in symbolic ritual behavior in a form closely parallel to that of the Asmat dancer and the squirrel monkey.

Mock Combat

In the Sepik River area among Auyu of southern New Guinea near Maprik, arguments within a residential community, and even those between adjacent communities, are at times settled without resorting to warfare or raiding, but are left to the individuals involved. The parties concerned are usually fully armed and, with great shouting, feign combat; they stand at opposite sides of the village hurling insults and epithets loudly at each other, hurling spears or shooting arrows at each other, which miss or at least fail to cause severe injury. Later they continue to snap their bow strings, without actually discharging the arrows, or they merely go through the motions of spear throwing or arrow shooting. In their anger, they often pace back and forth, or go around in a circle, to periodically stop and confront their adversary with recriminations.

The argument is witnessed by the entire community, who withdraw quietly to a distance, and the performers, aware of their audience, state their grievances as they hurl defiant words at each other. Often their kinsmen or friends arm themselves, but stand to one side as "seconds." These vocal battles of mock combat are very reminiscent of those reported in bands of monkeys as the vocal battles of *Alouatta palliata*. Similar threatening and gesturing, without actual combat, have been reported for baboons and other animals.

Echopraxia and Echolalia as a Means of Alleviating Anxiety and Establishing Friendly Contact

During explorations in South America and Melanesia, I have several times made first-known civilized contact with primitive peoples. Among the Tjitak headhunters of West New Guinea on one such occasion, I suddenly became aware of a strange human behavior pattern with which I was already familiar from similar tense moments of early contact with South American Indian groups, and elsewhere in Melanesia.

It consists of the frightened, tense, and anxious people, whose community I had entered, acting in a way which at first seemed a self-conscious, stylized effort to be friendly, but which was, I slowly became aware, an almost unconscious ritual copying of any facial expression or gesture, and at times of even any utterances I made. Thus, if I stroke their chin, belly, or shoulder, or reached for a handshake, they reciprocated in kind; if I nodded, they nodded; when I smiled or laughed, they too did the same; if I walked to their houses with an arm over a shoulder in an attempt to be friendly, they promptly reciprocated. Even if I greeted them with a word not of their language, they at times repeated my utterance. When a colleague pointed out that people at a distance whom I was not aware of, nor had observed, were similarly mimicking my every stance and gesture—crossing their legs when I crossed mine, grasping their hands behind their backs or rubbing them through their hair when I did this—we attempted systematic observations of the matter during these fleeting and demanding moments of early contact.

I have now seen the phenomenon four times, with totally different groups, in first or early contact situations. It is not unlike the phenomenon of echopraxia and echolalia described in the neurological literature for certain pathological states. Monkeys in captivity are noted for a great deal of mimicry interaction with humans, yet they demonstrate less of such behavior when observed in natural bands. This repetitive reciprocation of quantitatively metered responses seems to be a major feature of teasing, joking, or testing behavior between children in some groups at play. It is also seen in captive gorillas and chimpanzees playing with man. In our contact with primitive peoples, this mimicking behavior appears to be carefully balanced between fright and anxiety, fight or flight reactions, and playful smiling and laughter. It is not unreasonable to propose that to mimic and to attempt to respond in such a way as to behave like a strange newcomer, who is a source of fear and anxiety, may be an unconscious anxiety-alleviating mechanism aimed also at evoking a reciprocal controlled and controllable, and thus friendly, response in the strange visitor. Imitation and mimicry have had high survival value in natural selection.

Aesthetic Creativity and Individualism in the Primitive Band

A highly developed art in the form of carvings, sculpture, painting, dance, or song is a rarity among the hundreds of New Guinea cultures. Areas in which art has flourished, such as among the Asmat and the people of the Sepik River plain, and the Papuan Gulf, are few. During a sojourn of several years among most Highland peoples, an ethnologist will often find only a few items of craft or aesthetic production worth collecting. In contrast, within the first hour of visiting in traditional Asmat or Sepik villages, one could see enough carvings and decorative art to fill a museum. The same differences between groups

exist for music; some groups have elaborate song and dance, whereas with others the Euterpean and terpsichorean arts are rudimentary. For myths and other oral tradition, the same contrasts apply. It would obviously be a matter of importance for us to understand the social conditions which, in rare societies, make of each individual a sensitive participant in the arts and of many individuals, artists.

We have not been able to answer the question of what makes the creative arts flourish in a culture, as in the Dordogne in Upper Paleolithic times, the Indians of the Pacific Northwest in North America, in Bali, and among the Asmat and Sepik peoples of New Guinea. On the other hand, I have been investigating two cultures, which are noteworthy for lack of artistic creation, whose repertoire of song, dance, carving, and other art is woefully small. It is of interest that the two groups I have in mind—the Tarahumara of the Sierra Madre Occidentales in Mexico, and the Anga, or Kukukuku, peoples of Eastern New Guinea—have very weak social pressure for conformity, with no central leadership or strong community ties. In both cultures, an enormously self-sufficient individualism is stressed, and the male head of the hamlet or expanded family encourages his sons to be like himself, dependent on no one for his livelihood, suffering no one to make decisions for him, or to give him instructions, directions, or commands. Such individualism seems to demand widely separated family residences or homesteads, or very small villages or hamlets. Thus the mountain Arapesh studied by Margaret Mead have very inferior artistic production and live in very small hamlets of rugged individualists, while the neighboring Abelam with flourishing visual arts live in large, socially complex, tightly packed villages. This individual family unit or small band or hamlet psychology seems to have rarely been associated with the flourishing of the arts.

Why Are They Primitive?

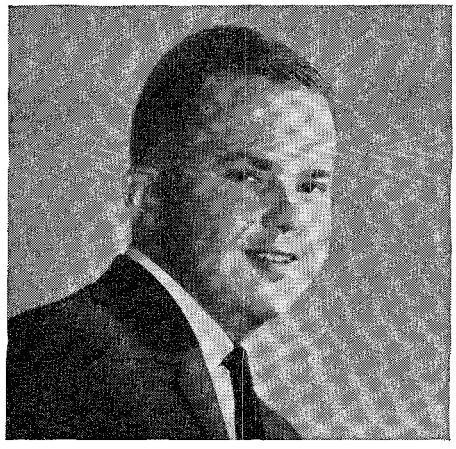
When surveying contemporary primitive societies, one cannot refrain from asking: Why have they remained in or returned to the Stone Age? Thus, why have peoples who are now, or were but recently living in a Stone Age culture remained so long at this historically early level of human social development? These are valid questions. We know of populations in South American jungles and in Melanesia who, under the impact of warfare and other pressures, have returned to hunter-gatherer life from an already attained stable life as primitive agriculturalists. The Guayaki Indians of South America, who still today roam as hunters through forests of Paraguay without clothing or shelter, were, some 300 years ago, farmers settled around Jesuit missions. In the backwaters of the Upper Amazon, there are communities of unclothed hunter-gatherers and primitive agriculturalists, which have their origins in the literate and eminently civilized "conquistadors."

On the other hand, we may ask how great is the leap from the Stone Age to our modern civilization? There are numerous examples on record of those individuals who have tried to make it in one lifetime. More often than not, the records are of unsuccessful attempts, which serve to bolster our conviction of our own incredible progress since those ancestral times. Thus, the sad story of Ishi, the California Indian who finally emerged to write his biography with Professor Theodora Kroeber of Berkeley. One wonders if these stories may not be akin to those of so-called feral children who, on emerging from their wolf lairs, have never succeeded in mastering human language or society. The question always remains as to how defective they were to have gotten into the wolf lair in the first place, or whether they had foregone human contact during "critical periods" for the learning of language and social behavior. However, we now have the recent stirring account of Alfred Moari Kiki, who writes in his biography, *Kiki—Ten Thousand Years in a Lifetime*, of his boyhood in a Stone Age New Guinean society, to his training as a pathologist and his current role as leader of the Pangu Parti who are demanding immediate self-rule for New Guineans.

That whole communities of Stone Age warriors converged with the modern civilized world in one generation has been demonstrated repeatedly in the past several decades in New Guinea.

It is by no means certain that fire, cooking, the domestication of animals, and the planting of grain, the use of metals, the wheel, writing and a phonetic alphabet, and many other discoveries have been made more than once—or a very few times—in history. That the tribes of northern Europe would have yet emerged to civilization, had they not been infected with it by direct contact from Asia Minor and through the Mediterranean, is doubtful.

We are left with the observation that communication between groups, and a government that maintains peaceful roads of contact and commerce, is essential to the civilized state. Without it, civilized man can fall back into illiteracy and savagery in only a few generations. Civilization is a fragile flower of human evolution, and all races and groups of men are quickly stimulated to such blooming, if once exposed to it, without impedence to the material rewards that it may bring them.



Doug Taylor got his B.S. degree in Electronics Engineering in 1967.

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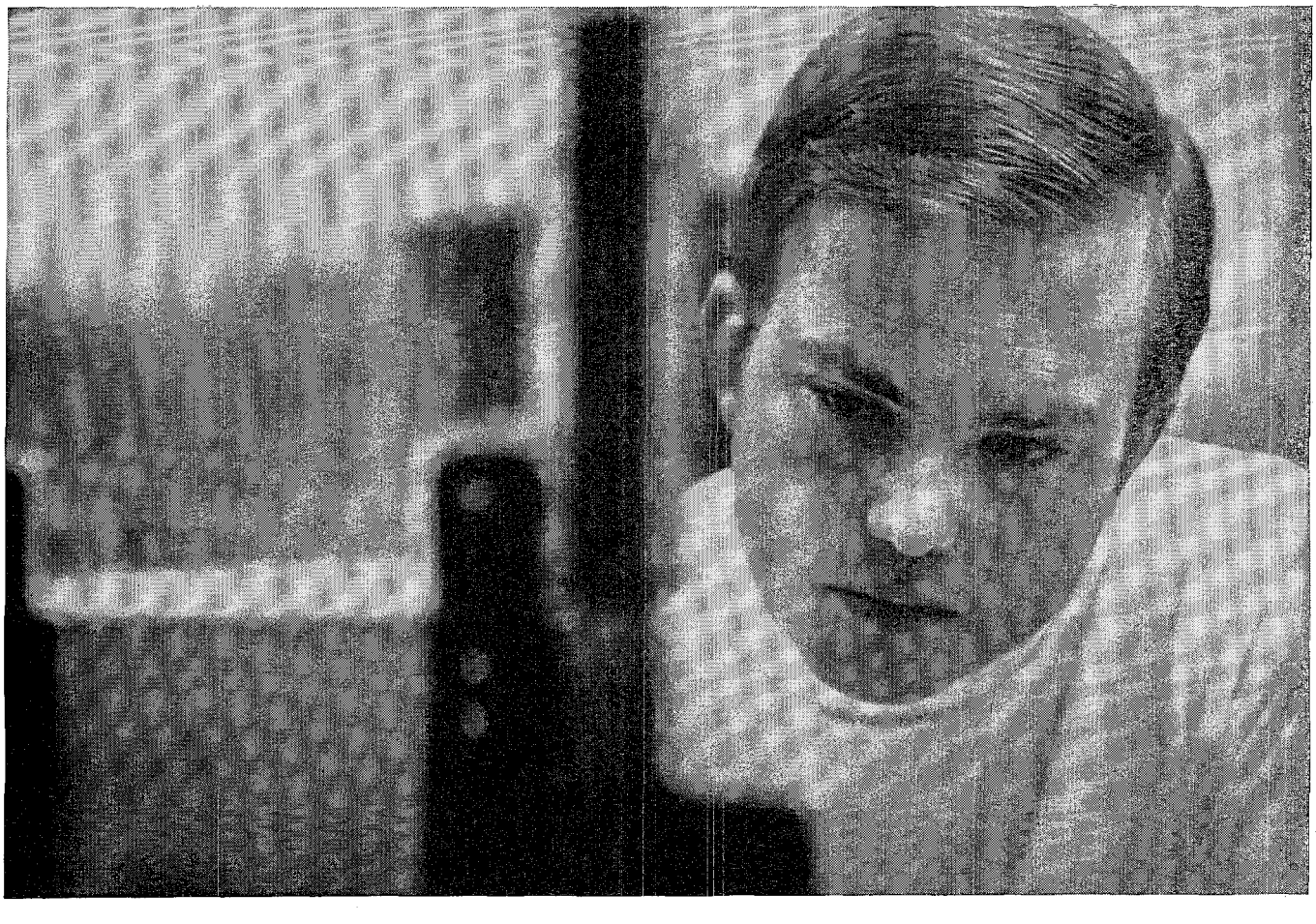

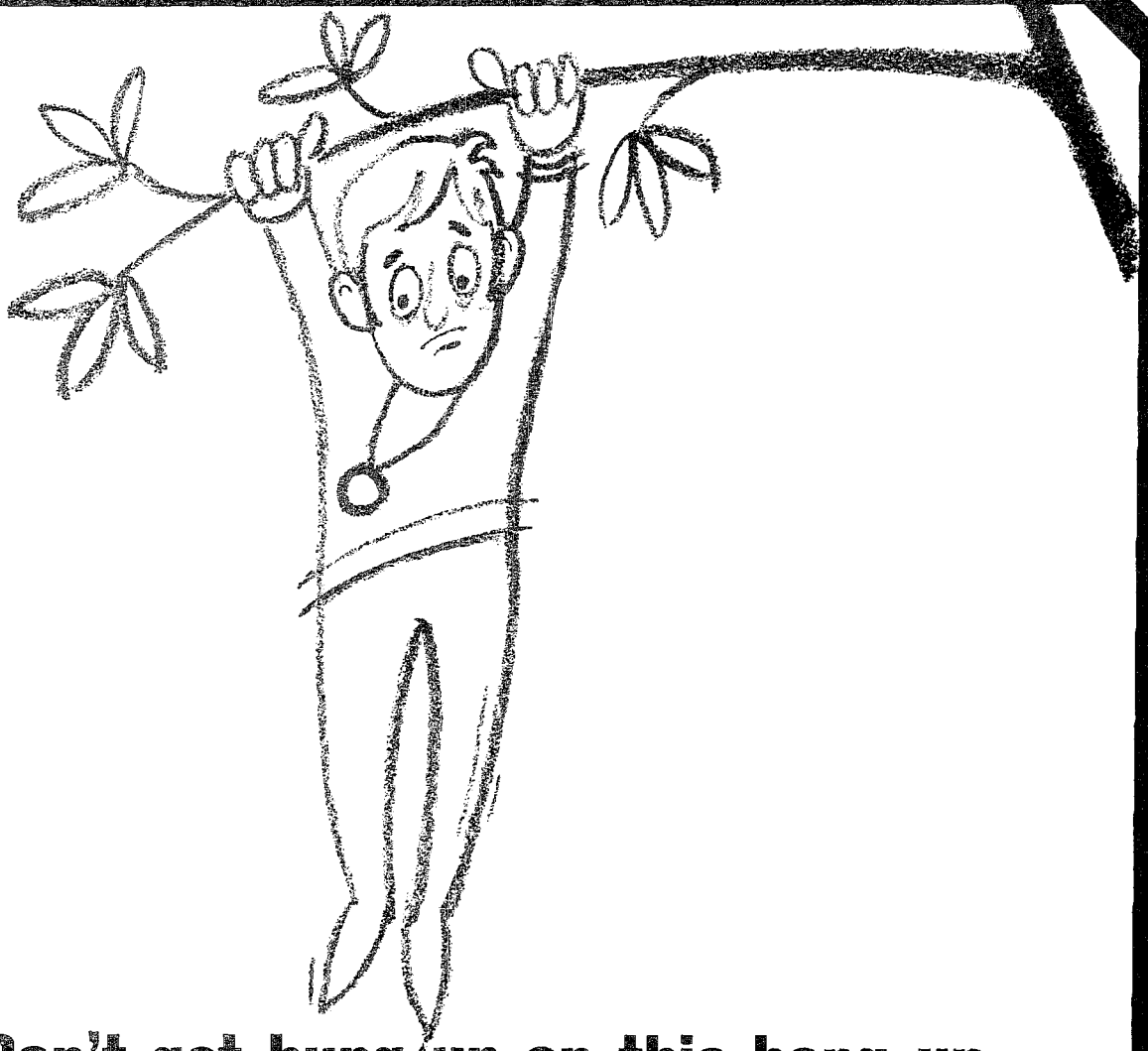

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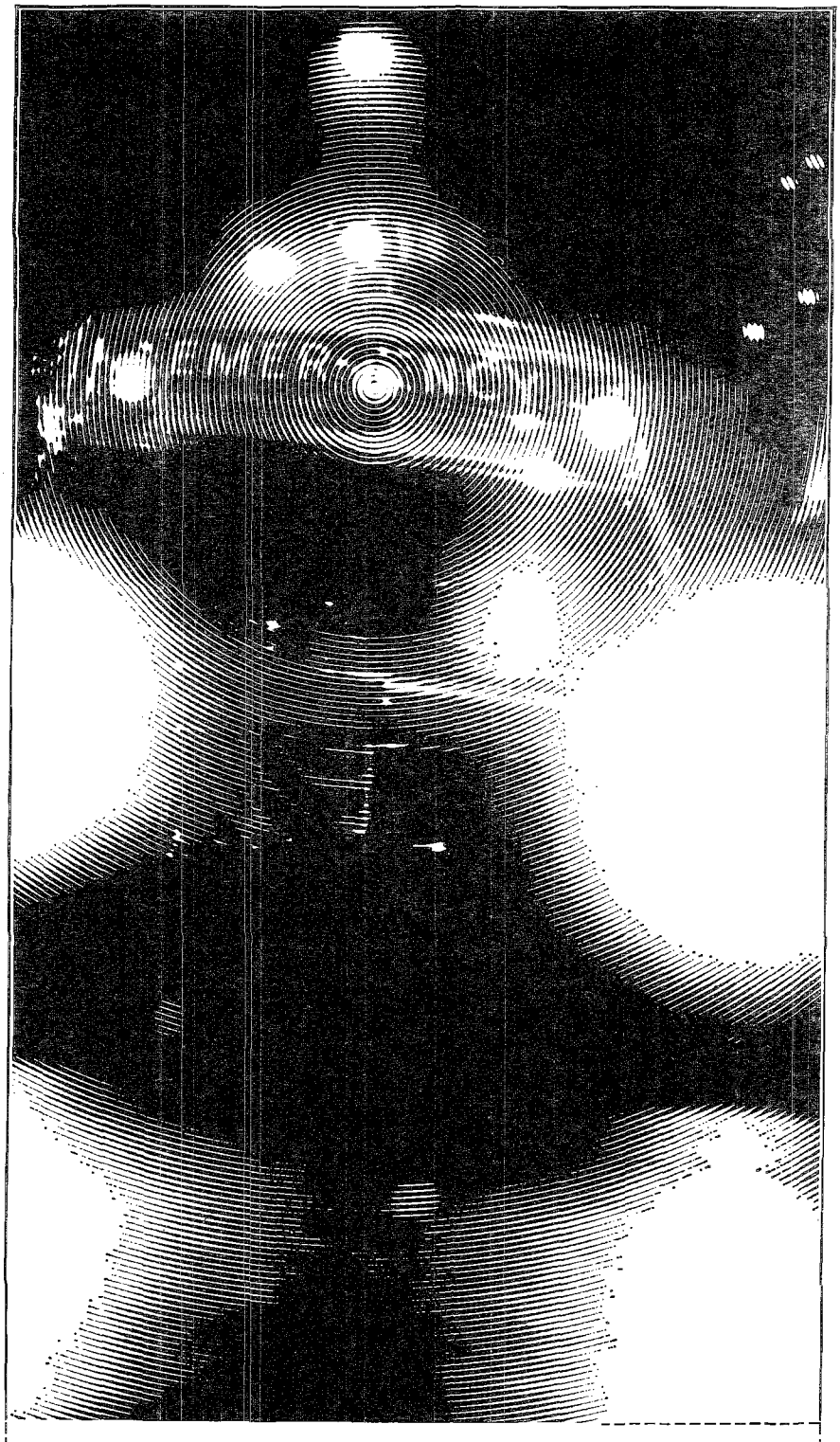

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