THE BRAIN'S GENERATION GAP: SOME HUMAN IMPLICATIONS

by Paul D. MacLean

There is a saying that something does not exist until you give it a name.[1] There has, of course, always been a gulf between generations, but call it by any other name, none would be more expressive for our times than the "generation gap." As with the familiar spark plug, the word gap implies a critical distance. Too wide or small a gap, and the whole social engine breaks down. The ever-critical need for an evolving and thriving society is just the right gap for sparking constructive ideas. For those of us on the older side, the problem is not just the gap but also the gas mixture. The bright spark of youth is making this increasingly clear. In calling for a cultural tune-up, young people insist that it is pollution from the mixture of outworn political, social, and commercial ideas that primarily destroys our environment, poisons human relationships, and threatens atomic blistering of the whole world. They also point out that the twentieth-century doctrine that businesses and institutions must either continue to grow or perish no longer makes sense. It is somewhat like saying, "I want a tumor."

It is my purpose here to call attention to another generation gap that applies to the human brain. It is a gap that is generally unfamiliar to young and old alike. Yet it exists in every one of us, and, adding to countless generations, makes the familiar generation gap seem insignificant by comparison. And it is an extremely critical gap because learning to recognize it, understand it, and live with it may be more crucial than anything else to worthwhile survival.

To understand the brain's generation gap it is necessary to think in evolutionary terms. Propelled by our imagination which exceeds the speed of light, we will go back 250 million years to the age of

Paul D. MacLean, M.D., is chief of the Laboratory of Brain Evolution and Behavior, National Institute of Mental Health, Bethesda, Maryland. This paper is based on two illustrated lectures, entitled "The Brain's Generation Gap: Some Human Implications" and "Survival Mechanisms of the Triune Brain: Some Hopeful Aspects," presented, respectively, at the 138th annual meeting of the American Association for the Advancement of Science, December 28, 1971, Philadelphia, Pennsylvania, and at the G. Burroughs Mider National Institutes of Health lecture, February 9, 1972, Bethesda, Maryland.

reptiles, when animals which never learned to talk began to crawl into the brain of man. In evolution (see plate 1) the primate forebrain expands along the lines of three basic patterns characterized as reptilian (green), paleomammalian (red), and neomammalian (blue). The result is the remarkable linkage of three brain types which are radically different in structure and chemistry, and which, in an evolutionary sense, are countless generations apart. We possess, so to speak, a hierarchy of three-brains-in-one—a triune brain.[2] Or, stated another way, we have a linkage of three biocomputers, each with its own special kind of intelligence, sense of time, memory, motor, and other functions.

Although my proposed scheme for subdividing the brain may seem simplistic, the fact remains that the three basic formations are there for anyone to see, and, thanks to improved anatomical, chemical, and physiological techniques, stand out in clearer detail than ever before. It should be emphasized, however, that the three brain types are in no sense separate, autonomous entities, although they are capable of functioning somewhat independently.

Man's Reptilian Brain

In discussing the three brain types we will need only a handful of anatomical terms. Let us deal first with the largest generation gap and look at the reptilian-type brain. In mammals the major counterpart of the reptilian forebrain includes a group of large ganglia which, for short, I will call the "R-complex." In ganglia the nerve cells appear to be in large clumps, whereas in cortex they are arranged in layers. The Koelle stain for cholinesterase brings out

---

Plate 1.—Diagram of hierarchical organization of three basic brain types which in the evolution of mammals become part of man's inheritance. The three types are radically different in structure and chemistry and in an evolutionary sense are countless generations apart (after P. D. MacLean, "The Brain in Relation to Empathy and Medical Education," *Journal of Nervous and Mental Disease* 144 [1967]: 374–82).

Plate 2.—Copper-colored areas show how a stain for cholinesterase demarcates part of the R-complex in animals ranging from reptiles to primates. With the fluorescent technique of Falck and Hillarp, these same structures glow brightly because of their high content of dopamine. The pallidal part of the R-complex (not shown) does not fluoresce. No extant reptiles represent the forerunners of mammals. Birds are an offshoot from the *Archosauria* ("ruling reptiles") (adapted from A. Parent and A. Olivier, "Comparative Histochemical Study of the Corpus Striatum," *Journal für Hirnforschung* 12 [1970]: 75–81).

Plate 3.—Lower drawings showing medial view of brains of rabbit, cat, and monkey illustrate that the cortex of the old mammalian brain (limbic system) is found as a common denominator in the brains of all mammals. Shown in red, it occupies the limbic lobe which forms a border around the brain stem. The cortex of the new mammalian brain (shown in white) mushrooms late in evolution (from P. D. MacLean, "Studies on Limbic System ('Visceral Brain') and Their Bearing on Psychosomatic Problems," in *Recent Developments in Psychosomatic Medicine*, ed. E. Wittkower and R. Cleghorn [London: Pitman & Sons, 1951], pp. 101–25).

Plate 1

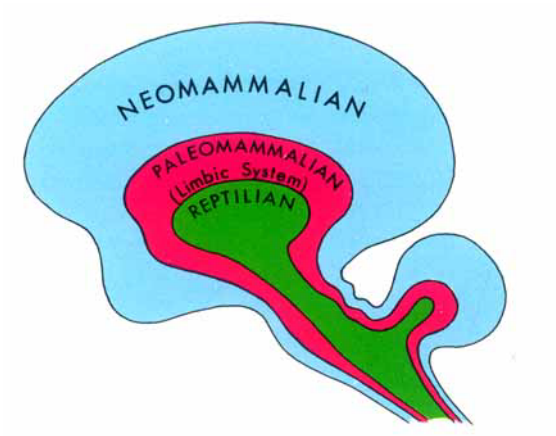


Plate 2

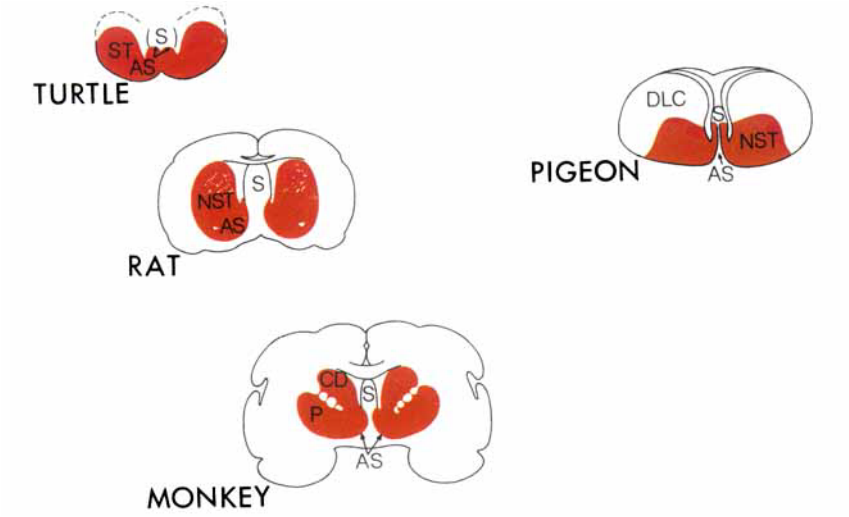


Plate 3

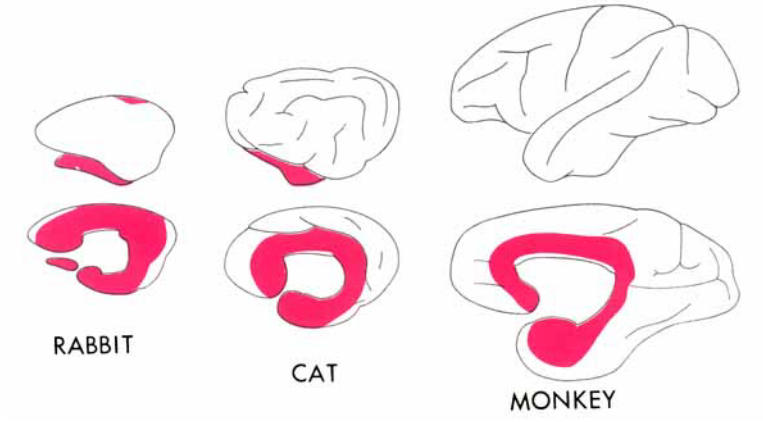


Plate 4

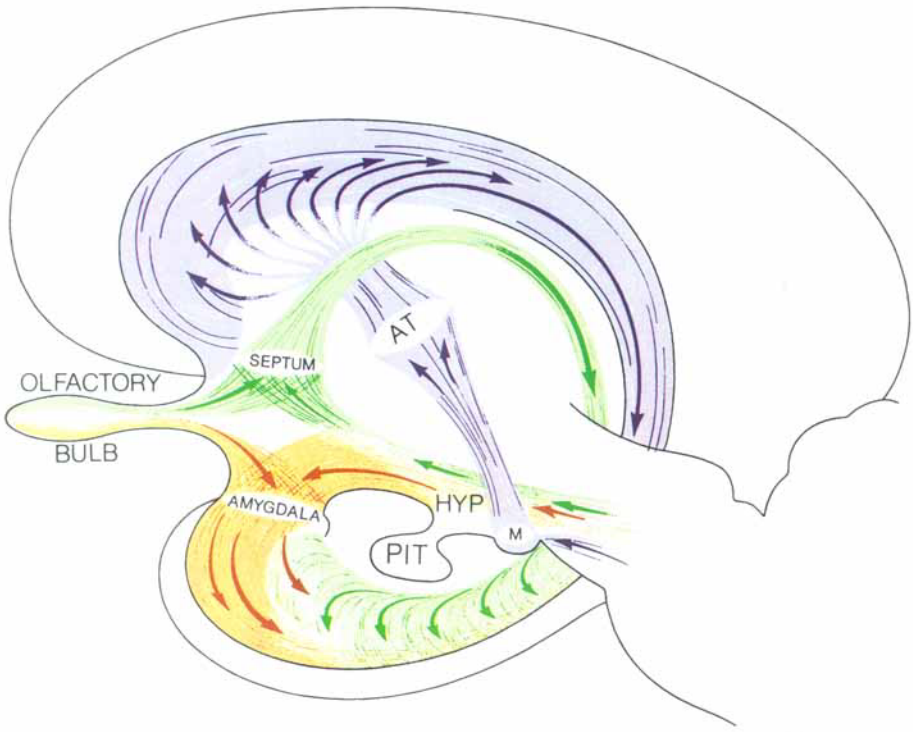
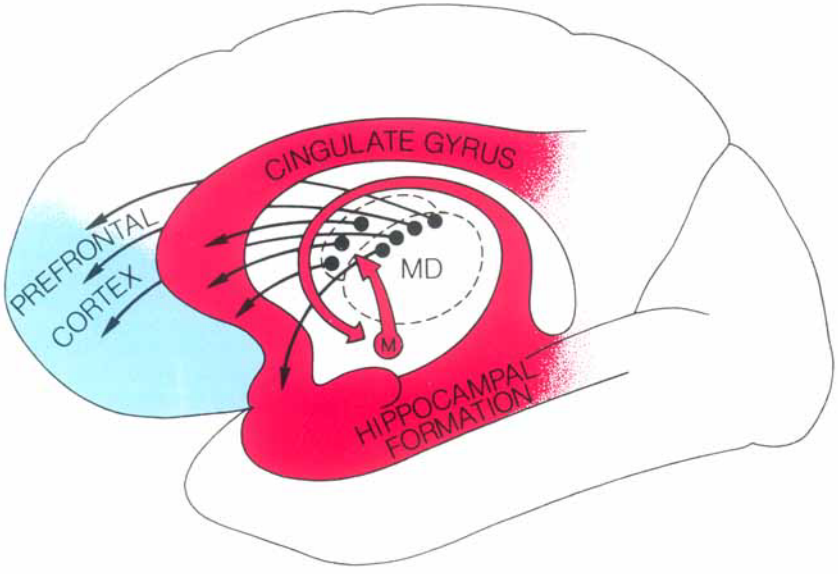


Plate 5



a remarkable chemical contrast between the R-complex and the two other brain types. The copper-colored areas in plate 2 illustrate how this stain sharply demarcates the R-complex in animals ranging from reptiles to man. In using the fluorescent technique of Falck and Hillarp, it is also striking to see how these same structures glow with a bright green sheen because of the high content of the biogenic amine called dopamine.[3] The pallidal part of the R-complex (not shown in plate 2) does not fluoresce.

Despite 150 years of experimentation involving stimulation and destructive lesions, remarkably little has been learned about the functions of the R-complex. Perhaps because of a major interest in learning, memory, and motor mechanisms, there has been a failure to ask the right questions. The finding that large lesions of the R-complex may result in no incapacity of movement challenges the traditional view that this ancient part of the brain is simply a motor apparatus. At our new Laboratory of Brain Evolution and Behavior we are investigating the role of the R-complex in natural forms of animal behavior. We are testing the hypothesis that it is basic for such genetically constituted behavior as selecting homesite, establishing and defending territory, hunting, homing, mating, forming social hierarchies, and the like. We also hope that this work will shed light on neural mechanisms underlying compulsive, repetitious, ritualistic, deceptive, and imitative forms of behavior.

In a moment I will illustrate what we are doing along these lines by describing experiments on squirrel monkeys relevant to aggressive, territorial behavior. The British naturalist, Eliot Howard, emphasized that the establishment of territory may be an essential preliminary to mating and breeding.[4] Ethologists have confirmed and extended his observations.[5] Ritualized, aggressive displays are used in establishing and defending territory. All kinds of trappings are used to make an aggressor look big, colorful, and menacing. In a number of species hair tufts are part of the regalia. Some tribal warriors display the hair of the armpit as a threat.[6] According to Hingston, the direction

---

PLATE 4.—Scheme of medial view of the brain with three main subdivisions of the limbic system shown in orange, green, and purple. See text for explanation of their respective functions in emotional and sexual behavior. Abbreviations: *AT,* anterior thalamic nuclei; *HYP,* hypothalamus; *M,* mammillary bodies; *PIT,* pituitary (after P. D. MacLean, "Contrasting Functions of Limbic and Neocortical Systems of the Brain and Their Relevance to Psychophysiological Aspects of Medicine," *American Journal of Medicine* 25 [1958]: 611–26).

PLATE 5.—Diagram of the human brain indicating how the limbic system (red) establishes connections with the prefrontal cortex, one of the most recent developments of the neomammalian brain (from P. D. MacLean, "The Brain in Relation to Empathy and Medical Education," *Journal of Nervous and Mental Disease* 144 [1967]: 374–82).

of the hair follicles on man's shoulders indicates that he once wore a mane, giving him a bulky disguise like that of a football player.[7] All that many of us have left to show for this is gooseflesh.

The aggressive display of some reptiles and lower forms is the same as their display in courtship and mating. We have found a parallel situation in the small South American primate, the squirrel monkey.[8] As shown in figure 1, the male monkey has a genital display in which it vocalizes, spreads one thigh, and directs the erect phallus toward the other animal. Sometimes females will also display.[9] The display is seen in its most dramatic form when a new male is introduced into an established colony of squirrel monkeys. Within seconds all males begin to display to the strange monkey, and if it does not remain quiet with its head bowed, it will be viciously attacked. We found that the incidence of the display among males in a colony is a better measure of dominance than the outcome of rivalry for food.[10] It is a remarkable parallel, as I said, that like some reptiles

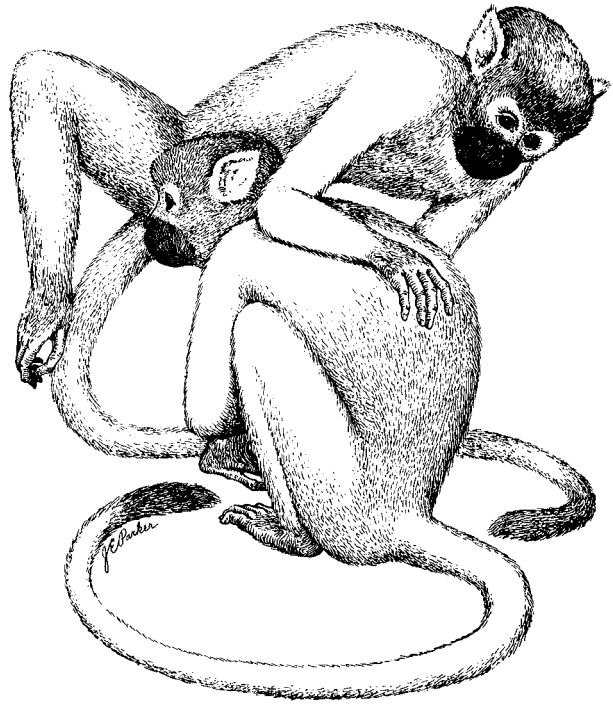


FIG. 1.—Posture of genital display of squirrel monkey seen in aggressive encounters with males or prior to copulation with females (from P. D. MacLean, "New Findings Relevant to the Evolution of Psychosexual Functions of the Brain," *Journal of Nervous and Mental Disease* 135 [1962]: 289–301).

and lower forms, the display of this primate is the same in courtship as in the show of aggression.

The display is also used as a form of greeting, and I have described one variety of squirrel monkey (fig. 2) that will regularly display to its reflection in a mirror.[11] We refer to the mirror-displaying animal as the "gothic" type, because the ocular patch comes to a peak over the eye like a gothic arch, whereas we call the other type "roman," because the patch is round like a roman arch. Ploog has since shown that the display is an innate form of behavior because the infant squirrel monkey born in isolation will display as early as the second day to another monkey.

Using a mechanically operated device for systematically testing mirror display of gothic-type monkeys in their home cages, I have made observations on how removal of parts of the brain affects the display of monkeys that have previously demonstrated close to perfect performance over a period of several weeks. There have been numerous cases in which large bilateral removal of parts of the old and new mammalian brains have had no perceptible effect on either the somatic or genital aspects of the display. I have found, however, that after lesions of the pallidal part of the R-complex monkeys may no longer

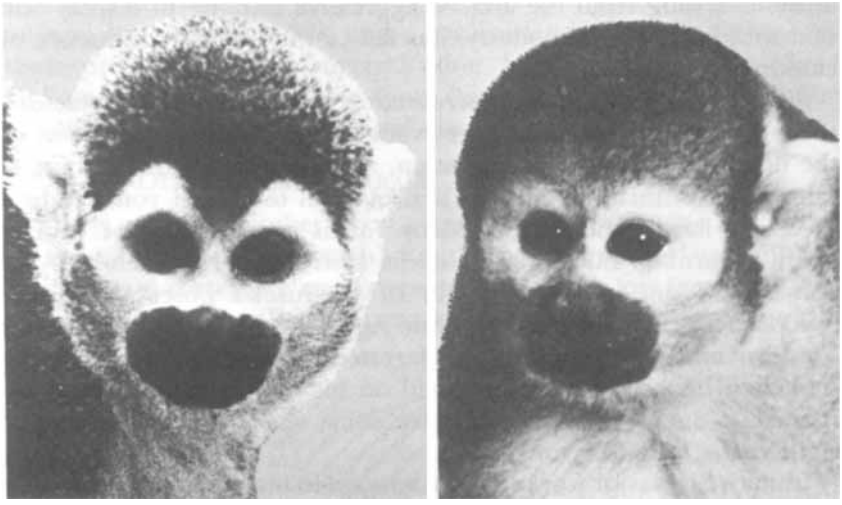


FIG. 2.—Two varieties of squirrel monkeys referred to as "gothic" and "roman" because of pointed and rounded shape of ocular patch above the eye. Both varieties use the same type of genital display in the communal situation, but only the gothic type will consistently display to its reflection in a mirror (from P. D. MacLean, "Mirror Display in the Squirrel Monkey, Saimiri sciureus," *Science* 146 [1964]: 950–52).

show any inclination to display during several weeks or months of testing.[12] Yet, when introduced into our testing colony, such animals have been able to defend themselves and even overpower the dominant animal. Without a test of the innate display behavior one might conclude that these animals were unaffected by the loss of brain tissue.

The findings of these experiments suggest that the R-complex may be part of a neural repository for species-specific forms of behavior, illustrated in the present experiments by a genital display variously used in the show of aggression, courtship, and in greeting.

It is a long leap from monkeys to man. Do the comparative observations have any human relevance? There is much suggestive evidence. For example, in primitive cultures in different parts of the world the territorial aggressive implications of genital display are illustrated by houseguards—stone monuments showing an erect phallus—used to mark territorial boundaries. It is as though a visual, urogenital symbol is used as a substitute for olfactory, urinary territorial markings of animals, such as the dog with a well-developed sense of smell. Gajdusek, in an article on Stone Age man,[13] has suggested a parallel between the display behavior of our squirrel monkeys and certain rituals of Melanesian tribes. Is it possible that primitive man may have learned that by covering himself he reduced unpleasant social tensions arising from the archaic aggressive impulse to display and that this, rather than modesty, has led to the civilizing influence of clothing?[14]

Since the display of the squirrel monkey involves imitative factors, the work I have described is relevant to the important question of the neural mechanisms of imitation, about which almost nothing is known. Look through current neurological texts and you will find the topic hardly mentioned. Many forms of imitation, of course, involve learning, but basic to this is a strong natural tendency to imitation. I am reminded again of Gajdusek's observations. He describes an encounter with a Stone Age tribe which had never seen Western man before. He was interested to observe that when he scratched his head or put his hand on his hip, the whole tribe did the same. Such imitation may have some such protective value as signifying, "I am like you."

Imitative behavior works in myriad ways to maintain group identity and promote group survival. The case of the autistic child is an example of the devastating effects of an inability to imitate. If there is anything that marks an autistic child, it is an apparent incapacity for natural imitation.

It is relevant to mechanisms of imitation that partial representations

have the capacity to trigger reciprocative behavior. In the case of the squirrel monkey, the reflection of a single eye is enough to elicit a full display.[15] It is well known that in reptiles and lower forms, part of a dummy may trigger complicated sequences of reciprocative behavior in territorial defense, mating, and the like. On a recent visit to the zoo I was unable to attract by any means the attention of the common lizard until I sketched the shadowgram shown in figure 3 and held it up before the window. Immediately it came over and gave its full display. Here, it seems, we are almost next door to the ink blots of a Rorschach test! Is it possible that cubistic art—depicting, for example, the entire human figure in two dimensions (eyes and buttocks in the same plane)—owes some of its appeal to the portrayal of archetypal patterns and partial representations? Walking as we do through a world of shadows, we shall be lucky if we ever see even the broad outlines of neural mechanisms underlying these and other cryptopsychic processes that are the very guts of everyday forms of human behavior. In the question that follows, let me just mention a few garden varieties that have the flavor of instinctive behavior in reptiles.

It is traditional to belittle the role of instincts in human behavior, but how should we categorize those actions that stem from a predisposition to compulsive and ritualistic behavior; a proclivity to prejudice and deception; a propensity to seek and follow precedent as in legal and other matters; and a natural tendency to imitation? All these propensities have survival value, but they are double edged and can cut both ways. In our times this is especially true of imitation to which I will return in the final discussion.

Man's Old Mammalian Brain

We turn next to the other great generation gap—the one pertaining to the old mammalian brain. Recalling that reptiles have only a rudimentary cortex, we must presume that in the lost forms between reptiles and mammals there was an expansion and elaboration of

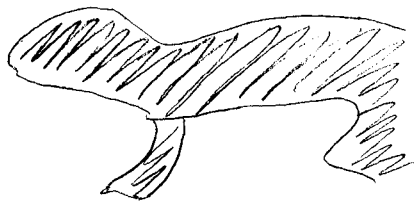


Fig. 3.—Partial shadowgram of the common lizard (Iguana iguana). See text for explanation.

the primitive cortex. Reminiscent of the invention of television, this cortex provides the animal a better means for viewing its environment and learning to survive. In both lower and higher mammals (plate 3) the old cortex occupies a large convolution which Broca in 1878 called the "limbic lobe" because it surrounds the brain stem. Shown here in red, it forms a common denominator in the brains of all mammals. In 1952 I suggested the term "limbic system" for the limbic cortex and structures of the brain stem with which it has primary connections.[16] The limbic system, let it be emphasized, represents an inheritance from lower mammals. Until thirty years ago it was believed to be primarily an olfactory brain and hence was called the "rhinencephalon." As I will explain later, evidence has accumulated that this brain derives information in terms of emotional feelings that guide behavior required for self-preservation and preservation of the species.

Compared with the limbic cortex, the new cortex (plate 3) is like an expanding numerator. It mushrooms late in evolution, culminating in man to become the brain of reading, writing, and arithmetic. Mother of invention and father of abstract thought, it promotes the preservation and procreation of ideas.

The primitive limbic cortex is structurally less complicated than the new cortex. Although it was once believed to receive information mainly from the olfactory and visceral systems, we have shown by recording from single nerve cells in awake, sitting monkeys that signals also reach it from the visual, auditory, and somatic senses. There are clinical indications that the combined reception of information from the inside and outside worlds is essential for a feeling of individuality and personal identity.[17] Contrast this situation with the neocortex, which receives signals largely from the visual, auditory, and somatic systems, suggesting that the new cortex is primarily interested in happenings in the external environment.

Also in contrast to the new cortex, the limbic cortex has large direct, cable-like connections with the hypothalamus which integrates the performance of mechanisms involved in self-preservation and the procreation of the species.

The limbic cortex is further distinguished from the neocortex by its chemistry. By means of radioautography we found that the limbic cortex has a much higher uptake of radiomethionine than the neocortex, indicating a greater turnover of protein. Some parts of the limbic cortex are also chemically distinctive because of high concentrations of acetylcholine, norepinephrine, serotonin, zinc, and other substances.[18]

The limbic system comprises three main subdivisions which in plate

4 are colored orange, green, and purple. Note that the two subdivisions in orange and green are closely related to the olfactory apparatus, whereas the pathway to the third division bypasses the olfactory apparatus. Definite evidence of the role of the limbic system in emotional behavior is based on clinical observations. Neuronal discharges in or near the limbic cortex may result in a broad spectrum of emotional feelings. Discharges involving the orange-colored region trigger unpleasant feelings, such as fear and anger, associated with the struggle for survival. We found that stimulation of this region in cats and monkeys elicited behavior related to feeding, fighting, and self-protection. It therefore appears that this part of the limbic system is primarily concerned with self-preservation.

Curiously enough, until quite recently there was only indirect evidence that the forebrain was involved in sexual behavior. We found, however, that stimulation in parts of the subdivision colored green results in genital and other sex-related manifestations. This and other kinds of evidence suggests that this subdivision is involved in expressive and feeling states that promote the procreation of the species.[19]

It is relevant to aggressive and violent forms of sexual behavior that pathways from the orange and green subdivisions converge near a locus in the hypothalamus that is involved in angry behavior. In figure 4 I have used the shield of Mars as a symbol for stimulation effects involving the mouth and his spear for genital responses. In following the symbols along the pathways into the hypothalamus, we find a reconstitution of the warrior Mars in a region responsible for angry behavior. Within a narrow compass in this region, stimulation elicits penile erection, angry behavior, biting, and chewing. As fighting is frequently a preliminary to both feeding and mating, these findings suggest that nature uses the same neural mechanisms for combat in each situation.

The close relationship between oral and genital functions is presumably due to the olfactory sense, which, dating far back in evolution, plays a primary role in both feeding and mating. You will notice in plate 4 that the main pathway to the third subdivision of the limbic system, colored purple, bypasses the olfactory apparatus. In evolution this subdivision outgrows the two other divisions and reaches its greatest size in man. According to Stamm and Slotnick,[20] destruction of its large gyrus interferes with maternal behavior. We have found that stimulation in parts of this subdivision elicits basic sexual responses. These and other findings suggest that the remarkable expansion of this subdivision reflects a shift in emphasis from olfactory to visual influences in sociosexual behavior.

It is one of the seven wonders of the brain that limbic epileptic

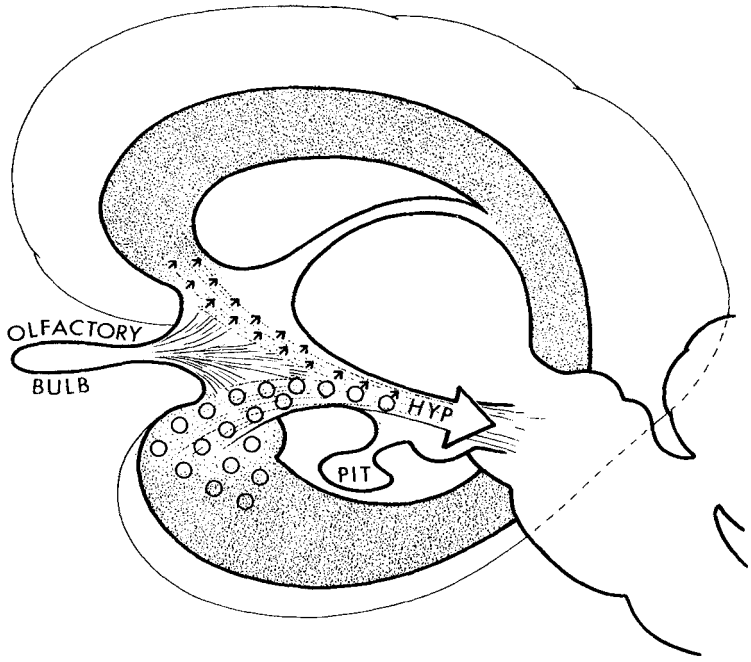


FIG. 4.—Diagram of medial view of brain showing points where electrical stimulation elicits oral (○) and genital (♂) responses. In following the symbols for the shield and spear of Mars along pathways into the hypothalamus, one finds a reconstitution of the warrior at a place where electrical stimulation results in angry and defensive behavior (adapted from P. D. MacLean, "Man and His Animal Brains," *Modern Medicine* 32 [1964]: 95–106).

discharges have the tendency to spread in and be confined to the limbic system, not directly involving the neocortex. Elsewhere, I have referred to this condition as a "schizophysiology."[21] In everyday functioning this schizophysiology possibly contributes to inexplicable conflicts between what we think and what we feel. Sometimes the emotional impact of the two apparent intellects working at cross-purposes has the survival value of getting us over impossible hurdles. At other times it may just as unpredictably lead to personal tragedy or set the stage for nervous breakdown. It is relevant to understanding neural mechanisms underlying mental illness that limbic discharges may induce symptoms characteristic of endogenous, as well as toxic, psychoses, including those precipitated by psychedelic drugs. Such discharges, for example, may result in (1) feelings of depersonalization, (2) distortions of perception, (3) paranoid delusions, and (4) hallucinations.[22]

I have already referred to striking chemical differences of the three brain types. There is brain-wave and other evidence that some of the psychotherapeutic drugs owe their salutary effects to a selective action on the limbic system and the R-complex.[23]

In connection with science and discovery, it is of special interest that limbic discharges may trigger eureka-type feelings expressed by such words as "this is it, the absolute truth; this is what the world is all about."[24] The feeling is free floating, being attached to no specific solution or idea. It has the quality of what most of us feel when we make a discovery or arrive at the solution of a problem. Kepler provides a vivid illustration. He was drawing a figure on the blackboard for his class "when an idea suddenly struck him with such force that he felt that he was holding the key to the secret of creation in his hand."[25] Although his inspiration proved to be wrong and lingered as an *idée fixe* the rest of his life,[26] it led to the formulation of his three famous laws. Ironically, it seems that the ancient limbic system provides the ingredients for the strong affective feelings of conviction that we attach to our beliefs, regardless of whether they are true or false!

Before some concluding remarks, I want to emphasize again that the three basic brain types are not to be considered as separate, autonomous entities. They are extensively interconnected, but just how they are connected and function together as a triune brain is a major problem for future investigation.

Making Three Brains Operate as One

I suggested earlier that the reptilian brain is a neural repository for innate forms of behavior. Other bits of evidence indicate that with the evolution of the old and new mammalian brains, nature economically uses the reptilian brain as a storage mechanism for parroting learned forms of emotional and intellective behavior acquired through limbic and neocortical systems.[27] We are all aware, for example, that once having acquired a verbal or other skill, we can later repeat it, so to speak, almost instinctively. Indeed, if we stop to think how we do it—as, for example, playing a musical piece learned by heart—it may interrupt the continuity of performance. As Plutarch taught us to say, habit is "almost a second nature."

There are clinical indications that the reptilian- and old mammalian-type brains lack the neural machinery for verbal communication with the neocortex. Given this incapacity for verbal communication with these ancient cerebrotypes, there exists in each of us an unbridgeable generation gap—a gap that makes the familiar one seem tame by comparison. But to say that they lack the power

of speech is not to disparage their intelligence. Nor does it mean they can be relegated to the unconscious, when in actuality they may be wide awake. The need for more harmonious survival with our animalistic selves calls for new research approaches in crypto-psychology. Among the challenges are finding better ways for coping with the communication gap and discovering more perceptive measures of human intelligence.

At the international level the most explosive issue is the problem of controlling man's reptilian intolerance and reptilian struggle for territory, while at the same time finding a means of regulating our soaring population. Language barriers among nations present great difficulties, but the greatest language barrier lies between man and his animal brains.[28]

Part of the poisonous fallout of today's hurry-up attitudes may be that we are getting out of step with our animalities. It seems that ever since *Sputnik* our educational leaders have been planning our existence as though we had to satisfy only our neocortex. Designed to come up with new ideas, the neocortex appears to thrive on change. With its imagination that exceeds the speed of light, the neocortex may be able to keep up with the present accelerated tempo of life through speedreading, help of computers, and other contrivances, but the two animal brains which are our constant companions move at their own slow pace. They have their own biological clocks and their own sequential, ritualistic ways of doing things that cannot be hurried. Courtship, for example, does not lend itself to the rules of speedreading. The reptilian and limbic brains have survived millions of years of evolution, and it is evident that no genetic tailoring will remove them overnight from the brain of man. Although we now anticipate public transportation at rocket speeds, we will still have to move at a horse-and-buggy pace with our animal brains. Once this is realized, we may achieve a quality of life that will bring greater contentment. Perhaps this is what today's youth has been trying to tell us.

I have not forgotten my reptilian promise to return, in conclusion, to the question of imitation. With worldwide television, the matter of imitation looms more important than ever in human affairs, not only as it applies to fads, fashions, and drug cultures, but, more significantly, to forms of mass hysteria and violence. It has become almost a dictum that "imitation rules the world." There is abundant evidence from animal behavior studies of Calhoun, Myers, and others that the conditions of crowding are conducive to aggression and combative behavior.[29] In addition to bringing out aggressiveness, crowding also increases the opportunities for imitation. One may

therefore suppose that violent behavior can lead to a kind of vicious circle through the positive feedback of imitation. It is one of the perversities of television that it brings crowding, violence, and imitation right into the living room. It was stated recently that by the age of fourteen the average child will have seen eighteen thousand murders on television.

But as Koestler reminds us, "The damages wrought by individual violence . . . are insignificant compared to the holocausts resulting from self-transcending devotion to collectively shared belief systems."[30] He lays the blame on man's paranoid streak. Yet the paranoid streak would not get anywhere without the primitive forces of imitation. In the past, these imitative forces have afforded survival on the grand scale under the label of "militant nationalism." Today this brand of imitation is potentially more deadly than imitation is to science. To quote Koestler again, "Before the thermonuclear bomb man had to live with the idea of his death as an individual; from now on mankind has to live with the idea of its death as a species."[31]

After a few more clouds, I will point out one bright ray of hope. Because of our scientific emphasis on the control of natural phenomena, we tend to regard ourselves as separate from, and even superior to, nature. But the fact remains that we are one of nature's experiments, and we might justly wish that it would share our guilt for the violence that we do to ourselves and our environment. Nature, indeed, sets us a terrible example not only in regard to violence of storms, earthquakes, disease, and cancerous erosion, but also in exposing us on all sides to trickery, deceit, and treachery. The wonder is that man has ever been able to go straight! Indeed, if we were not a part of nature, it could be said that we had surpassed nature in a sense of honesty and altruism. For where else in nature can one look for an example that "honesty is the best policy"? When we are at our best, nothing makes us more unhappy than seeing living things suffer. And nothing brings greater satisfaction than to relieve suffering or to witness the relief of suffering. Recalling that the word "altruism" was coined as recently as 1853 by Auguste Comte and that the word "empathy" was given to us by Theodor Lipps about 1900, we gain intimations that the humanitarian movement is still in evolution.

Partly on the basis of new information mentioned in this paper, I would suggest that the capacity for empathic identification with others stems from the great development of the cingulate division of the limbic system and its articulation (plate 5) with a more recent expansion of the human brain—the prefrontal neocortex. There are clinical indications that the prefrontal cortex provides foresight in

planning for ourselves and others and that it also helps us to gain insight into the feelings of others. In the remarkable development of these structures which seem to be especially geared for promoting the welfare and preservation of the species, we find reason for hope that in the further evolution of man, human love and enlightenment will prevail over the forces of violence and destruction.

For weary mortals looking for relief from the constant drone of dismal news about the state of the world, I would suggest that they take up cerebral astronomy and study the three great galaxies of the triune brain.

NOTES

1. Harley C. Shands, "Outline of a General Theory of Human Communication," in *Essays in Semiotics*, ed. J. Kristeva, J. Rey-Debove, D. J. Umiker (The Hague: Mouton & Co., 1971), pp. 343–81.

2. P. D. MacLean, "The Triune Brain, Emotion, and Scientific Bias," in *The Neurosciences Second Study Program*, ed. F. O. Schmitt (New York: Rockefeller University Press, 1970), pp. 336–49.

3. A. V. Juorio and M. Vogt, "Monoamines and Their Metabolites in the Avian Brain," *Journal of Physiology* 189 (1967): 489–518.

4. H. E. Howard, *An Introduction to the Study of Bird Behavior* (Cambridge: University Press, 1929), p. 136.

5. For a lively, extensive review see Robert Ardrey, *The Territorial Imperative* (New York: Atheneum Publishers, 1966), p. 390; and also *The Social Contract* (New York: Atheneum Publishers, 1970), p. 405.

6. Desmond Morris called my attention to this observation.

7. Richard W. G. Hingston, *The Meaning of Animal Colour and Adornment* (London: E. Arnold & Co., 1933), p. 411.

8. P. D. MacLean, "New Findings Relevant to the Evolution of Psychosexual Functions of the Brain," *Journal of Nervous and Mental Disease* 135 (1962): 289–301.

9. D. W. Ploog and P. D. MacLean, "Display of Penile Erection in Squirrel Monkey (Saimiri sciureus)," *Animal Behavior* 11 (1963): 32–39.

10. Ibid.

11. P. D. MacLean, "Mirror Display in the Squirrel Monkey, Saimiri sciureus," *Science* 146 (1964): 950–52.

12. P. D. MacLean, "Cerebral Evolution and Emotional Processes: New Findings on the Striatal Complex," *Annals of the New York Academy of Sciences* 193 (1972): 137–49.

13. D. C. Gajdusek, "Physiological and Psychological Characteristics of Stone Age Man" (Symposium on Biological Bases of Human Behavior, California Institute of Technology, Pasadena, April 1970), *Engineering and Science* 33 (1970): 26–33, 56–62.

14. MacLean (n. 8 above).

15. MacLean (n. 11 above).

16. P. D. MacLean, "Some Psychiatric Implications of Physiological Studies on Frontotemporal Portion of the Limbic System (Visceral Brain)," *Electroencephalography and Clinical Neurophysiology* 4 (1952): 407–18.

17. MacLean (n. 2 above); "Implications of Microelectrode Findings on Exteroreceptive Inputs to the Limbic Cortex," in *Limbic System Mechanisms and Autonomic Function*, ed. C. H. Hockman (Springfield, Ill.: Charles C. Thomas, Publisher, 1972), pp. 115–30.

18. For review see P. D. MacLean, "The Limbic Brain in Relation to the Psychoses," in *Physiological Correlates of Emotion*, ed. P. Black (New York: Academic Press, 1970), pp. 129–46.

19. MacLean (n. 8 above).
20. J. S. Stamm, "The Function of the Median Cerebral Cortex in Maternal Behavior of Rats," *Journal of Comparative and Physiological Psychology* 48 (1955): 347–56; B. M. Slotnick, "Disturbances of Maternal Behavior in the Rat Following Lesions of the Cingulate Cortex," *Behaviour* 24 (1967): 204–36.
21. MacLean (n. 8 above).
22. MacLean (n. 18 above).
23. Ibid.
24. MacLean (n. 2 above).
25. A. Koestler, *The Sleepwalkers* (New York: Grosset & Dunlap, 1963), p. 624.
26. Ibid.
27. MacLean (n. 12 above).
28. P. D. MacLean, "Man and His Animal Brains," *Modern Medicine* 32 (1964): 95–106; "Alternative Neural Pathways to Violence," in *Alternatives to Violence,* ed. L. Ng (New York: Time-Life Books, 1968), pp. 24–34.
29. J. B. Calhoun, "Population Density and Social Pathology," *Scientific American* 206 (1962): 139–46; K. Myers, C. S. Hale, R. Mykytowycz, and R. L. Hughes, "The Effects of Varying Density and Space on Sociality and Health in Animals," in *Behavior and Environment,* ed. Aristide H. Esser (New York: Plenum Press, 1971), pp. 148–87.
30. A. Koestler, *The Ghost in the Machine* (New York: Macmillan Co., 1968), p. 384.
31. Ibid.