Paul MacLean and the Triune Brain

NIMH scientist believes that to understand ourselves, we have to figure out what our animal brains are up to

To understand what Paul MacLean is up to with his monkeys and lizards in the Maryland countryside, you have to know about therapsids, the mammal-like reptiles that roamed the earth about 200 million years ago, before the dinosaurs, when Africa and India were stuck together and no bird had yet chirped. We do not know much about these creatures, whether they vocalized, for example, or showed any interest in their young (reptiles do not as a rule); however, it is the descendants of the therapsids that give rise to the marsupials and the placentals—the two classes that make up today's mammals.

There is very little interest among scientists in the mammal-like reptiles, as the mainstream of brain research does not take much account of the triune brain, the mysteries of which MacLean has spent the last 22 years trying to unravel.

"Triune" is one of many neologisms coined by MacLean, who is director of the National Institute of Mental Health (NIMH) Laboratory of Brain Evolution and Behavior. The term refers to evidence that the human brain is really three brains in one: the ancient reptilian

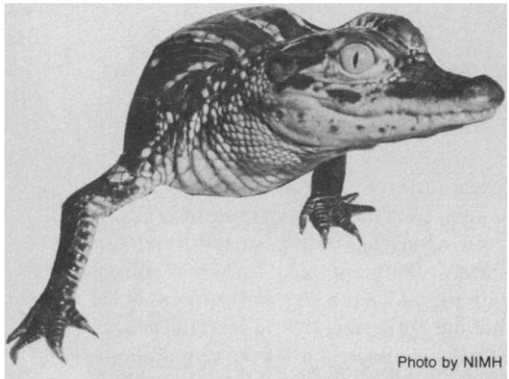
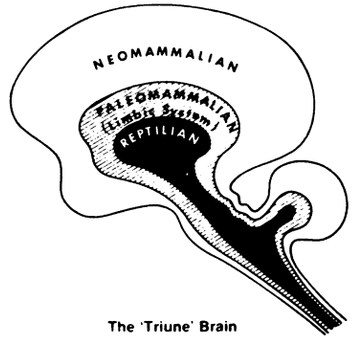


Photo by NIMH

Baby alligator, used for research on thermoregulation and reproductive behavior.

core, which MacLean calls the R-complex; the old mammalian brain (or visceral brain, or limbic system), and the neocortex, which is the main reason humans are different from animals. The three brains are anatomically separable and chemically distinct. They also, according to MacLean, contain the formats



The 'Triune' Brain

or potentials for distinct groups of behaviors.

MacLean is not one of those scientists whose work has captured the popular imagination, although astronomer Carl Sagan makes extensive use of it in his book *The Dragons of Eden*. One reason MacLean is not better known is that his particular approach to brain research is virtually unique. Ethologists, for example, study animals' natural behaviors without trying to correlate them with brain structures. Brain research with human subjects focuses on neocortical functions. Psychobiologists observe the effects on learning and memory of lesions in animal limbic systems. MacLean, however, is following a path that has as yet been lightly trod—a search for natural behaviors embedded in the most ancient part of the brain, the R-complex. "Instinct has been kind of a dirty word for some time," he observes. Yet what else to call the challenge display of the green *Anolis* lizard or the stalking behavior of the Komodo dragon, certainly neither of which was learned at their mothers' knees?

Science visited MacLean one bright May day, on his 65th birthday, at the animal center, a sprawling complex built in Poolesville, Maryland, in 1971. He was feeling philosophical, wondering how his work was going to help him make sense of things before the day of reckoning; but then, he has always felt philosophical.

Born in the town of Phillips, New York, the third of four sons of a Presbyterian minister, he says "I can't remember when I haven't been driven . . . to get some feeling of what life is all about, how we happen to be here." He majored in English at Yale and planned to go to Edinburgh to study philosophy. But a family illness precipitated a change of heart that catalyzed his growing feeling that he was never going to come up with anything new studying philosophy. So he went to Edinburgh anyway and instead prepared to become a doctor. On his return he entered Yale Medical School, but his interest in the brain was dampened by the prevailing intellectual currents: "In those days the mind wasn't in the head." Scholars, captured by reflexology, saw the brain as a sort of push-button mechanism whose functions were parallel to but separate from the activity of the mind. MacLean therefore went into pathology, and later decided to specialize in cardiovascular disorders.

It was World War II that got him back on the track of the brain. Packed off to the Solomon Islands with Yale's 39th General Hospital Brigade, he found himself working with psychiatric casualties. It was a "very dramatic introduction to psychiatric problems"; he realized that "pure form can't act on pure form—there has to be something we recognize as a behaving entity."

On his return he did research on psychomotor epilepsy at Massachusetts General Hospital, then went back to Yale Medical School where he had a dual appointment in physiology and psychiatry. In 1957 he was invited to NIMH, where he headed the section on limbic integration and behavior.

MacLean became involved in the brain at a time when concepts about the functions of its major structures were undergoing radical revision. It was he, for example, who in 1951 coined the term limbic system to encompass what neuroanatomist J. W. Papez called the limbic lobe, and related structures. This area had been known as the rhinencephalon or "nosebrain" because it was thought that its primary function was olfactory. "Limbic system" denoted the new recognition that this area was far more important than previously thought, indeed the seat of emotions as well as of olfactory, oral, and sexual behaviors.

The 1950's was also a time when experiments were indicating that the corpus striatum (part of what MacLean calls the R-complex) did not do what people thought. It had been assumed respon-

0036-8075/79/0608-1066$00.75/0

sible for motor activity; yet lesions in the area were not having any observable effects. So scientists were concluding that the corpus striatum "was one of the silent parts of the brain."

MacLean thought differently. He was fascinated by what was revealed by temporal lobe epilepsy—"one of those cruel experiments by nature" that "tells you more about what goes on in the human brain than any other clinical entity." One begins to perceive that "emotions are very often merely the reflections of what's already started" in even deeper structures.

So he headed for the countryside and a hundred million years further back in evolution. "Our part [of the animal center] was really built to test the hypothesis that the R-complex is very important for integrating the kinds of behavior involved in self-preservation and preservation of the species and prosematic [nonverbal] communication." He designed his work with the belief that running animals through mazes in the laboratory was not the way to find out what their brains were made for; that "the corpus striatum might not be silent if we looked at animals interacting with each other in a seminatural environment."

> The R-complex contains built-in formats for very specific behaviors.

The work has been slow and difficult—"it took a long time to get in the right place"—but by interfering in the R-complex of lizards and squirrel monkeys MacLean has established that the ancient brain shared by all vertebrates is not silent and not, in higher animals, merely a vestige, but that it contains built-in (or "hard-wired" as the psychobiologists say) formats for very specific behaviors.

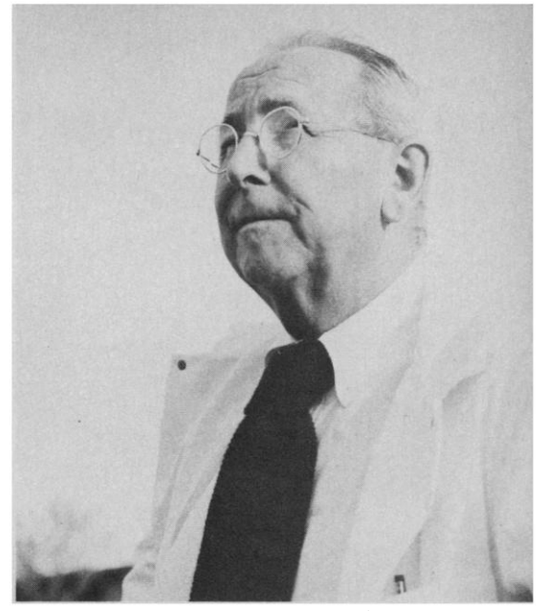
MacLean, with his penchant for neologisms, has categorized these in five basic groups: "isopraxic," behaviors in which two or more members of a group are doing the same thing; "perseverative," which covers routines and rituals such as courtship displays; "reenactment," meaning habits such as repeatedly following the same game trail; "tropistic," responding to partial representations of things, such as the marking on prey; and deceptive behavior.

Into one or more of these five modes can be ordered everything that makes up the reptilian way of life—hunting, homing, mating, establishing territory, fighting, and so forth, including communication. The display behaviors are what MacLean labels prosematic communication—reptiles as a rule do not vocalize, the auditory sense being more important to higher forms of life.

Reptiles are ruled by routine and ritual. According to MacLean, there are two basic aspects of their behavioral profiles—"like two mountain ranges." The first is the animal's "master routine." A lizard, for example, does the same thing in the same order every day: it emerges cautiously from its dwelling place, basks awhile to get its temperature up (it has no inner thermal regulation, which makes for tremendous energy savings), defecates, goes hunting, eats, has a siesta, does more errands, basks again, and returns home. The second mountain range is a repertoire of four basic display behaviors. One is the signature display, an assertion that "I am I"—used for greeting or recognition or even when there is no one else around—involving puffing up the throat fan, pushing up with the front legs, and head bobbing. Then there are two kinds of challenge or territorial display: distant and near. Another is the courtship display, and finally the submissive or assenting display involving lowering of the head.

MacLean has spent years nailing down the location in the R-complex of one type of prosematic behavior in one species: the greeting display of the squirrel monkey. He discovered that one kind of squirrel monkey, the Gothic monkey, so-called because markings over its eyes are the shape of a Gothic arch, will display to its image in a mirror. This is useful because it can be studied independent of social variables. (A very similar species, the Roman squirrel monkey, does not display to its mirror image.) MacLean found that the creation of lesions in the limbic system and neocortex has little or no impact on this display. But lesions in the globus pallidus (part of the R-complex) cause the animal to become indifferent to its image. Similar lesions in the R-complex of the green *Anolis* lizard eliminates that animal's challenge display.

In reptiles, birds, and mammals, MacLean has written, "the R-complex is as much the bedrock of the forebrain as the Laurentian shield is to the North American continent." This being so, it is tempting to look for the reptile embedded in human behavior, and MacLean is always ready to yield to temptation. He took *Science* out to look at a pen of turkeys. Every time he clapped his hands or said "hey there" it precipitated a chorus of gobbles—an isopraxic response. "Just like a political rally," he said gleefully. (He says that damage to the R-complex not only stills the group gobble response but interferes with a turkey's inclinations to stick with the group.) The R-complex is so strongly implicated in social conformity that MacLean has even toyed with the notion that a defect in brain development may contribute to the extraordinary creativity of some people. Observing that Einstein was a nonconformist and a loner, he has written that "some individuals may become creative because of a constitutional incapacity for imitation . . . a defect of the nervous system that might interfere with the intercommunicative isopraxic process" and throw a person back on his own devices.



Paul MacLean Photo by C. Holden

To MacLean, there is plentiful evidence of the reptile at work in human beings. Arthur Bremer's stalking of George Wallace is a dead ringer for the prey-seeking behavior of the Komodo dragon, which will patiently stalk a deer for days on end. The young people flocking to Woodstock reminded MacLean of pigeons whose homing instinct had gone awry. And committee meetings (which MacLean has spent his life trying to avoid) are hardly different to him from the struttings and preenings and status displays that go on in a monkey colony.

MacLean obviously does not feel that neocortical activity plays much of a role in committee meetings. And although he has hailed the neocortex as "the mother of invention and father of abstract thought," he finds that much business, human and animal, can be done without it. "People don't like to hear this business about the neocortex," he observes.

Gothic squirrel monkeys

"We have been brought up being told the neocortex does everything," an assumption that has filtered up from the days of John Locke, who saw the mind as a *tabula rasa*, and later the behaviorists, whose contention that all behavior is learned is a way of dismissing the evidence that subcortical structures already have their own ways of dealing with the world. MacLean believes that the people who are enamored of theorizing about the differences between the left (rational, verbal) and right (nonverbal, intuitive) cerebral hemispheres are missing the boat somewhat. "I think they've got a lot of stuff maybe too high upstairs"—that is, many of the creative, emotional, and spiritual impulses ascribed to the right hemisphere are more properly attributable to the limbic system. "The hemispheres are equipotential," he asserts. "I see no evidence for a quadrune brain."

To show how little the cortex accounts for in some creatures, at any rate, MacLean brought out a dish of a half-dozen white mice, two of which had been decorticated by means of suction through the ear. He said the operation had no effect on mouse behavior—mating, breeding, rearing young—and he suspected that their maze-running abilities would not be much affected either.

MacLean also believes people underestimate the influence of the limbic brain. Observations of patients with psychomotor epilepsy back at Massachusetts General provided a rich assortment of insights on the role of the limbic system. A limbic storm, explains MacLean, is like a power blackout in which the lights in the emotional system are temporarily extinguished. People are known to do amazing things while undergoing an epileptic seizure—surgeons perform operations, for example—but afterwards they remember nothing. Because subjectively "something doesn't exist unless it's tied up with an emotion." And epilepsy, by wiping out the system that mediates between the upper and lower brains, clears the way for the old R-complex to show itself. People develop reptilelike automatisms. MacLean says, for example, that a person acting belligerent while in a seizure forgets learned fighting behaviors and will resort to a stiff-legged, off-balance, arm-swinging stance much like that of a sumo wrestler—and very like the challenge display of both the lizard and the gorilla. It's as though the behavior was "packaged and handed up the phylogenetic tree," says MacLean, who can't get over the wonder of it all.

But what seems most to affect MacLean is something else illuminated by epileptic seizures. It is contained in the "aura" an epileptic feels before the lights go out. During this time a person can experience a whole gamut of feelings, from intense hunger and thirst to rage, grief, fear, and profound joy. It is the ecstasy of a mystic or a person having a drug experience. It is a feeling of oneness with the universe, a perception that "this is the truth, this is it." We all act on the basis of what we perceive to be true and real, says MacLean, but the "this is it" feeling is not supplied by the rational cortex but by the seat of emotions. MacLean has observed the behavior of monkeys after part of the limbic system is destroyed by lesions in the temporal lobe. They will eat nuts and bolts and feces indiscriminately because the part of the brain that says "this is it" (food) is out of order.

"We try to be rational, intellectual, to be wary of our emotions. But as far as we have been able to tell to this day—and this is probably the most fundamental thing we have learned or ever will learn about the nervous system—the only part of the brain that can tell us what we perceive to be real things is the limbic brain." That works well in facilitating basic survival behaviors, but what about beliefs and ideas? Our limbic structures go ahead and tell us "this is it . . . but this probably isn't it."

MacLean, who feels keenly the press of time, finds his work has helped shape for him an uncomfortable philosophical dilemma. Since our "rational" perceptions of truth are merely cortical rationalizations for feelings welling up from the limbic pool, "I sometimes can't see my way around this life being no more than a cruel hoax."

MacLean is disturbed about peoples' "lack of introspection." He believes "we tend to ignore the internal world because our new brain is primarily oriented towards the external world. . . ." Yet "who worries much that their brain is made of these myriad sticky little mirrors," this avocado-textured globe of gray that has the bewildering ability to convey hardness and sharpness and shininess? It seems to MacLean that a "true representation of the world can no more exist in this jellylike mass than it can on the evening news."

MacLean thinks more people should be thinking about these things. In fact, he has proposed the creation of a new branch of knowledge which he calls "epistemics," which would combine brain sciences and psychology in an endeavor to explain the subjective self and its relation to the external and internal environment: "looking at things from the inside out" instead of the way science tackles things, which is the other way around. "We would have an entirely different appreciation of ourselves and the world if we could get a little deeper than the neocortex."

Certainly, it would seem that if educators, environmental designers, and indeed any of the human sciences looked at human behavior and needs from the perspective of the triune brain, there might develop some fresh new approaches to human problems. The two lower brains are not accorded much recognition because they cannot vote, so to speak, as they do not possess language. But, MacLean has written, "no matter what speed man attains with his new mammalian brain, he faces discontent unless he learns to accommodate to the horse and buggy pace of his animal brains."

MacLean becomes upset if one infers from his talk that human behavior is governed by mute, preprogrammed forces. On the contrary, he is optimistic for the race if we can learn to make use of the latest equipment evolution has provided, namely the prefrontal lobe of the neocortex, which appears to contain the uniquely human capacities for foresight and insight that make possible empathy and altruism—a conscious linking of inward well-being with the well-being of others.

All this, of course, is a long way from the challenge display of the green *Anolis* lizard. "People come out here asking what are our latest breakthroughs," sighs MacLean. "We have hardly begun learning our ABC's."

—CONSTANCE HOLDEN