"and" in it, whereas the rule he wants to apply works only for "or." So, he says, the job is to get that connective changed in order to apply the transformation that will shorten the left side. He looks for a transformation that turns "and" expressions into "or" expressions and elects to try it as his first step. Now, it is possible to find a fairly simple set of heuristic methods to describe what this subject is doing (e.g., his method is to make the propositions more important than the connectives in guiding the choice of transformations), and to predict that he would mention the left-shortening transformation before he adopted the connective-changing transformation. But if the only datum that the experimenter records is the bald fact that the subject's first choice of a transformation was the connective-changing transformation, it is impossible to see how the subject's strategy can be inferred.

It is tempting to say that a successful theory "predicts the subject's verbal behavior." In fact, no one is yet much interested in the verbal behavior as behavior, but only in the meaning of what is said. The subject may say, "Use number 8 next," or, "Let's try that one again," or any of a variety of equivalent verbal behaviors, yet these differences are ignored when testing the adequacy of the theory. Obviously, therefore, the interest lies in the subject's Plan, not in his specific actions.

When the psychologist says that his subject in these experiments was following such-and-such a Plan, or was using a particular metaplan for generating Plans to solve the problem, it is clear that this is a hypothetical statement. The Plan, or the metaplan, represents the psychologist's theory about that chunk of observed behavior. Obviously, we can never know whether or not we have *the* theory for any domain of inquiry. There is always a variety of alternative Plans that could have led the subject to exhibit the same behavior; the best we can hope to do is to select the simplest one compatible with all the facts. But, because this kind of ambiguity is such a pervasive feature of behavioral analysis, it is important to reduce it as far as possible. In this endeavor, the subject's verbal report has one great recommendation in its favor, because language, for all its notorious shortcomings, is still the least ambiguous of all the channels open from one human being to another.

CHAPTER 14

SOME NEUROPSYCHOLOGICAL SPECULATIONS

"A hole is to dig." The child amuses us with his operational definitions. "A knife is to cut." "A book is to read." "Milk is to drink." Each concept is defined by the concrete operations that it customarily evokes. The child is learning what to do with things. Or, to put it in our present language, the child is building up TOTE units by associating a perceptual Image used in the test phase with an action pattern used in the operational phase of the unit. The number of these TOTE units that a child must learn is enormous and he probably learns them, initially at least, by following this simple verbal formula that associates a subject with a predicate. It is not enough for the child simply to be able to name the object or to distinguish it from other objects. He must know what actions can be released when the test phase indicates the object is now at hand.

Children, however, are not the only ones who produce definitions of this type. Kurt Goldstein has widely publicized the fact that they can appear after certain types of brain damage.[1] The unfortunate patient is confronted with a knife, or with a picture of a knife. He is unable to supply the name. But if he is given the object, he knows how to use it. He may indicate that he recognizes it by making the gestures that imitate its use. He may even say, "It is to cut with," thus echoing the child. According to Goldstein's interpretation, this behavior on the part of the patient indicates an impairment of the "abstract attitude." The injury to the brain leaves the patient with a simpler, more concrete way of dealing with his world. Goldstein's famous theoretical analysis of the abstract-concrete dimension of mental life is one way of looking at the symptoms he describes in the patients. Another, more in keeping with the proposals made in this book, suggests that the brain can be damaged in such a way that some of the simplest processes of retrieving stored information cannot be performed, but other Plans normally initiated by the *object* are left intact. The patient may have lost the ability to execute the Plans involved in naming objects, but retained the ability to execute all other Plans. Or the patient may have lost the ability to recall a Plan by internal, verbal processes and be completely dependent upon external memory devices.

In any case, there seems to be good evidence for the age-old belief that the brain has something to do with the mind. Or, to use less dualistic terms, when behavioral phenomena are carved at their joints, there will be some sense in which the analysis will correspond to the way the brain is put together. Psychological problems may not be solved by making measurements on the brain; but some more modest aim may be accomplished. A psychological analysis that can stand up to the neurological evidence is certainly better than one that can not. The catch, obviously, is in the phrase "stand up to," since considerable prejudice can be involved in its definition. In any case, each time there is a new idea in psychology, it suggests a corresponding insight in neurophysiology, and vice versa. The procedure of looking back and forth between the two fields is not only ancient and honorable—it is always fun and occasionally useful.

The present authors determined to follow tradition and to look

[1] Kurt Goldstein and Martin Scheerer, Abstract and concrete behavior: an experimental study with special tests, *Psychological Monographs*, 1941, No. 329.

at the nervous system through the same theoretical spectacles. In fact, the brain was never far from the focus of discussion. Innumerable alternative interpretations of the available neuropsychological data were invented and discarded. In the hope of communicating the flavor of the arguments, this chapter reports a few of the ideas that were considered. However, the authors feel somewhat less than confident that they have discovered the one best line to pursue.[2]

The arguments revolved around a three-way analogy: The relation of a Plan to the mind is analogous to the relation of a program to a computer, and both are analogous to the relation of *X* to the brain. Question: What is *X*?

Of these three systems, the one we know most about is the computer. When a large, modern, general-purpose computer is turned on in the morning and sits there warming up, purring through its magnetic drums and scratching its multivibrators, it is not yet a true computing machine. It will not begin to act like a computing machine until it is given some instructions. Depending upon what kind of instructions it is given it may act like any one of an infinite variety of different computing machines that might have been built with the particular instructions locked in and unchangeable. But without the instructions, or program, the computer will do no processing of information. It may have all kinds of fascinating data stored in its memory or being fed into it from the outside, but without a program nothing can happen. A computer must have a program.

Now, as soon as someone suggests that people are like computing machines—and we hear that said every day—it should become clear that if the suggestion is true, people must have programs, also. If a man is like a computer, then the man must have somewhere available an organized set of instructions that he attempts to execute. That is to say, the man must have a Plan. By taking the analogy between man and computer with complete sincerity is one driven to

[2] One reason for much of the trouble in reaching an agreement about the way the brain works was that two of the authors stubbornly persisted in trying to talk about it in terms appropriate to the dry hardware of modern digital computers, whereas the third was equally persistent in using language appropriate to the wet software that lives inside the skull. After a decade of cybernetics you might think the translation from one of these languages into the other would be fairly simple, but that was not the case. The relation between computers and brains was a battle the authors fought with one another until the exasperation became unbearable.

search literally for the source of instructions that guide human behavior. The preceding pages try to describe the results of that search in psychological terms. Now we are interested to see what results the same attitude might produce in neurology.

In the broadest, crudest terms, what is the pattern to be transferred from computers to brains? There are many ways to build electronic computers, but most machines seem to involve a *memory*—where both the program and the data and any intermediate results and the final answer can all be stored—with facilities for transferring information into it and out of it, and a *processing unit*—where the actual operations of comparison, addition, multiplication, shifting, etc., are performed. The computer begins by taking the first instruction on the program and moving it from the memory to the processing unit. Whatever instruction is in the processing unit has control over what the machine will do, so it executes the instruction and goes on to the next instruction, etc., etc., with tremendous speed and blind persistence until an instruction tells it to stop. The instruction that is temporarily in the processing unit can be said to be the one that the computer is "attending to" at the moment. Note that the center of attention is a fixed place and that symbols are shifted *into and out of it* from the memory; the center of attention does not go wandering around through the memory itself, as a beam of light might scan a darkened room. No doubt there is nothing *necessary* about this pattern for computers, but at least it is familiar and we know that it will work.[3]

Is it possible to locate parts of the brain that correspond, however crudely, to these parts of a computer? To look for some particular place in the brain to represent a locus of consciousness, or a focus of attention, or whatever it is that corresponds to a computer's processing unit, is a naïve and impossible oversimplification. But the alternative metaphor—that a focus of activity moves about in the brain carrying consciousness with it from place to place—seems just as *ad hoc* in the light of available evidence. Regardless of what consciousness may be, however, the computer analogy would say to look for some particular place that could be used to store programs and data, that is, to serve as the memory. And it would tell us to look for another part of the brain into which an instruction could be transferred when the time arrived for the execution of that instruction.

After several months of discussion, the present authors were almost (but not quite) convinced that you could put the names of parts of the brain on slips of paper, scramble them up, draw two at random, assign them in either order to serve either as the memory or as the processing unit, and you would be able to interpret *some* evidence *somehow* as proof that you were right. One notion, for example, is that the cerebral cortex provides the memory unit, that the limbic areas somewhere house the processing unit, and that the cerebellum is a digital-to-analogue converter in the output system. The primary projection areas could provide short-term storage for images that would be operated upon by programs stored in the adjacent association areas. And so on. It is wonderful to see how these analogies can blossom when they are given a little affection.

Eventually, however, even the most optimistic theorist feels the need for evidence. What does the neurologist have to contribute to this discussion? In the broadest, crudest terms, once again, what pattern can be discerned in the organization of the brain?

Like Caesar's Gaul, the brain is divided into parts, a conceptual operation that always reflects a conviction that when two things live close together they probably cooperate with each other. A fourfold division of the forebrain can be made: first into an internal core *vs.* an external portion; then, each of these can be divided into two parts. The internal core is made up of limbic systems and a frontal "association area." The external portion is divided into projection systems for the different sense modalities and a posterior "association area."[4]

[3] We have considered only the possibility that the nervous system performs one operation at a time; an equally plausible alternative would be to allow different parts of the brain to perform computations at the same time. At the London Symposium on Mechanization of Thought Processes in 1958 Oliver Selfridge of the Lincoln Laboratory gave a talk entitled, "Pandemonium: a Paradigm for Learning," in which he described a hierarchical organization of parallel computers that could learn to recognize patterns and illustrated its operation in terms of a machine that would learn to recognize manually keyed Morse code. Ulric Neisser, in *Hierarchies in Pattern Recognition* (Group Report 54-9, Lincoln Laboratory, Massachusetts Institute of Technology, 9 October, 1959), explores some of the virtues of Pandemonium as a model of human cognition in general.

[4] The evidence on which these divisions are based has been summarized by Karl Pribram, Comparative neurology and the evolution of behavior, in A. Roe and G. G. Simpson, eds., *Behavior and Evolution* (New Haven: Yale University Press, 1958), Chapter 7, pp. 140–164.

These divisions are based on neuroanatomical evidence, but they also indicate relatively consistent differences in the kinds of psychological functions that they serve. Concerning the major division into an internal core and an external portion, Pribram comments as follows:

> [It is assumed] that the internal core is primarily related to changes in central nervous system excitability; that the external portion serves propagation of patterns of signals; that the internal core is primarily concerned in mechanisms necessary to the performance of behavior sequences while the external portion is related to informational processes necessary in discriminative behavior.[5]

The reader who has come this far through the present text should react with interest to this division of the brain into an internal part that handles sequences of acts and an external part that handles discrimination. Once the present distinction has been drawn between the Plan and the Image, it is almost inevitable that one should identify the internal core as the part of the brain involved in planning (i.e., "sequences") and the external portion as the part of the brain involved in our organized system of facts and values (i.e., "discrimination"). Thus, one begins to think of the internal core as a place that governs the execution of Plans; of the limbic portions of the internal core, along with their closely related subcortical centers, as if they performed the functions of a processing unit in a computer; and of the frontal lobe, which is the "association area" in the inner core system, as a "working memory" where various Plans could be temporarily stored (or, perhaps, regenerated) while awaiting execution.

There are problems with this schema, of course. One difficulty is the disposition of different motivational processes. Since it has been argued in these pages that values are part of the Image, consistency would demand that evaluation must be mediated by the external portion of the forebrain. However, current research on the limbic areas—the part of the inner core that might govern the execution of the Plan—suggests that they are involved in motivational processes in a most intimate fashion. Thus we seemed to face a dilemma, which took some careful analysis of the behavioral evidence to resolve. The matter is quite important, so let us pursue it here and now.

[5] *Ibid.*, p. 143.

Analysis of the functions of the limbic systems of the forebrain has been one of the outstanding achievements of neurophysiology during the 1950's. These systems are located deep in the center of the brain, and because they are difficult to get at surgically, they were neglected until recently. In spite of a great deal of research, however, the functions that these structures serve in normal behavior have eluded precise specification. The trouble stems from the fact that a wide variety of seemingly unrelated effects on behavior result when these regions are stimulated electrically or are surgically destroyed. Two different points of view have been adopted in the various attempts to explain the observed behavior: (1) The limbic systems comprise the substrate concerned with motivational and emotional behavior, motivation and emotion being conceived as primitive, instinctual, "visceral" reactions.[6] (2) The limbic systems are primarily concerned with "memory."[7] Clinical and experimental observations can be advanced, of course, to support both of these interpretations.

What sort of evidence is there for the first view, that the limbic systems are concerned with primitive motivational-emotional processes? For one thing, homeostatic mechanisms are abundant in the central core of the nervous system and are located especially around the third and fourth ventricles of the rostral end of the neuraxis. Take, for example, the thirst mechanism. Goats have been made to drink large quantities of water by injecting a few drops of concentrated table salt solution into the third ventricle. The osmoreceptors in this region of the brain are activated and the goats continue to drink water until an equilibrium is reached. That is to say, they drink until a sufficient amount of water is absorbed from the gut through the vascular system and into the cerebrospinal fluid to return its salinity to normal. This is the kind of "motivational" process one finds situated in the internal core. Should the present authors be embarrassed and revise their opinion about the relegation of dynamic factors to the Image on the basis of such evidence? Not at all. The thirst homeostat is a Plan, a relatively simple, innate TOTE unit.

[6] P. D. MacLean, The limbic system with respect to self-preservation and the preservation of the species, *Journal of Nervous and Mental Diseases,* 1958, 1, 1–11.

[7] B. Milner, Psychological defects produced by temporal lobe excision, in *The Brain and Human Behavior,* Research Publication, Association for Research in Nervous and Mental Disease, XXXVI (Baltimore: Williams and Wilkins, 1958), Chapter VIII, pp. 244–257.

As elsewhere, the TOTE phases, once they have been initiated, run themselves off until the incongruities that activated them are resolved. The organism will continue activities that tend to complete the TOTE sequence: i.e., the organism will show "intentional behavior." A statement that the animal "intends to quench its thirst" seems more appropriate than a statement that the animal values water. The distinction made in Chapter 4 between values and intentions is crucial here. What would really be surprising would be to discover that a lesion in the central core could cause a man to reverse, say, his preference for Rembrandt over Picasso, or for capitalism over communism. The evaluative factors involved in such choices as these must be mediated somehow in the external portion of the forebrain.

In the normal animal—one which does not have concentrated salt solution in its third ventricle—the number of swallows of water taken is determined by the amount of water the body needs, and the drinking will terminate long before there has been time for any dilution of the cerebrospinal fluid. What terminates the TOTE unit activity for drinking in this case? Presumably the number of swallows is recorded—we hesitate to say "counted," since that might be misunderstood as meaning that the animal pronounced the names of integers subvocally as it drank—and is compared with some predetermined number that depends upon the body's water balance. After each swallow the amount of drinking that has been done is compared with the predetermined amount that is to be done and when the two are equal the TOTE unit is terminated. How the number can be predetermined is not clear, but presumably it depends upon previous experience in some way. We might think of the information about how-many-swallows-are-needed-as-a-function-of-how-much-water-deprivation-has-been-endured as forming a part of the Image, a stored relationship, which must be drawn upon, activated, before the TOTE unit for drinking is set up for execution. Therefore, the present authors are not disconcerted to discover that lesions in the limbic systems of the central core disrupt the execution of such behavior.

This distinction between the automatic execution of TOTE units concerned with vital functions and the evaluation of these same functions in the Image can be illustrated by an actual case. Bilateral sur-

gical ablation of certain parts of the limbic systems characteristically result in excessive eating and obesity. One patient, who had gained more than one hundred pounds, was examined at lunch time. Was she hungry? She answered, "No." Would she like a piece of rare, juicy steak? "No." Would she like a piece of chocolate candy? She answered, "Um-humm," but when no candy was offered she did not pursue the matter. A few minutes later when the examination was completed, the doors to the common room were opened and she saw the other patients already seated at a long table, eating lunch. She rushed to the table, pushed others aside, and began to stuff food into her mouth with both hands. She was immediately recalled to the examining room and the questions about food were repeated. The same negative answers were obtained again, even after they were pointedly contrasted with her recent behavior at the table. Somehow the lesion had disrupted the normal relation between the evaluation of an object and the execution of Plans for obtaining it—between Image and Plan—a fact that we interpret as further evidence for a clear separation between value and intention, the two aspects of motivated behavior. Just how the lesion could have such an effect is a topic to which we shall return shortly.

What sort of evidence is there for the second view, that the limbic systems are concerned with memory? A large lesion in the limbic systems in man (more extensive than that described in the patient above) can produce a very odd type of memory loss. Patients with lesions in this part of the internal core of the forebrain are able to repeat correctly a series of digits that they have just heard for the first time. On this test of immediate memory they are practically as efficient as they were before the lesion occurred. Moreover, their memory for events prior to their surgical operation is apparently normal. But if distracted, they are unable to carry out a sequence of orders. If you are called away for ten or fifteen minutes in the middle of administering some test to such a patient, when you return he will not be able to continue where he left off. He will not recall where he was in the task. In fact, he will not even recall that there was any task or that he had ever seen you before. Such a patient can be directed to a grocery store where he can purchase the items on a written list without having to refer to that list any oftener than would a person with an intact brain. But once he has completed the shopping he does not recall what he is supposed to do with his purchases and he is completely incapable of finding his way home. Unless given new instructions at this point he will wander about aimlessly until something in the environment sets off a habitual reaction, such as waiting for a red light to change before he crosses a street. His behavior is not organized into a Plan, but rather is a mere concatenation of discrete acts.

On the surface, this peculiar defect of memory would not seem to have anything in common with the disturbed thirst and hunger mechanism mentioned above. Yet this patient's behavior illustrates perfectly what would happen if a person were unable to formulate Plans for remembering (cf. Chapter 10). Given an external Plan written out on a sheet of paper, the patient can carry on quite well.

Neurobehavioral studies conducted on animals support this notion that the limbic systems of the internal core of the forebrain play an essential role in the execution of Plans. Ablation and stimulation of various structures within these systems interfere with feeding, fleeing, fighting, mating, and maternal behavior. Two kinds of effects are obtained, depending on which of the major divisions of the limbic systems is experimentally involved.

The first kind of effect we have already met in the patient at lunch time. It seems to involve a failure of some sort in the test phase of the TOTE unit. Either the test will not indicate that the operational phase should occur, or the test will not indicate that it should terminate. If a lesion is made in one spot, the animal will starve to death in the presence of food. If the location of the lesion is shifted slightly, the animal will eat continuously as though it is impossible for him to stop. (Interestingly enough, preferences among foods are not disturbed; monkeys will still prefer peanuts to lab chow and prefer lab chow to feces.)

When a normal baboon is handed a lighted match for the first time he will grab it and put it into his mouth and perhaps set his whiskers afire in the process. He douses his snout in a water trough. When he is offered another lighted match he may reach for it, but he will stop before he grabs it, or if he does take it, he will fling it into the trough or out of the cage. If he has had an ablation of the amygdaloid complex—one of the major subdivisions of the limbic systems

—he behaves quite differently. If he reaches for the first match he will continue to reach for subsequent matches, and each time he will complete the entire sequence of putting it into his mouth, firing his whiskers, and dousing his snout. The test phase of the TOTE unit which initiates the actions of oral exploration cannot be modified in the light of experience.

In a similar fashion, sexual activity, once it has been initiated, will be displayed by these operated animals under circumstances in which normal animals show no such behavior.[8] And the effects of such lesions on fleeing can also be understood. The animals develop a conditioned avoidance reaction only with great difficulty: they apparently cannot establish the conditioned stimulus as part of the test phase of the avoidance behavior. And once conditioned avoidance has been established it is very easily extinguished—perhaps the animal is unable to terminate other TOTE units in which he is engaged in time to make the conditioned response.[9]

An effect of lesions in this part of the limbic systems, therefore, can be interpreted as a disruption of the test phase of different TOTE units. TOTE units that are already established may get their testing routines "jammed," so that the test always passes or always fails. And experience in the situation does not enable the operated animal to learn new testing procedures to substitute for the ones he has. An interesting sidelight on this inability to impose new tests on a TOTE unit comes from electrophysiological studies of cortical conditioning. The electrical activity produced in the visual cortex under ordinary circumstances by visual stimulation can be conditioned, after several paired auditory-visual presentations, to occur when only the auditory stimulus is given. The only selective ablation that is known to interfere with this conditioning process is that of the limbic structures we have been considering.[10]

Interference with the test phase of various TOTE units is only

[8] J. D. Green, C. D. Clemente, and J. de Groot, Rinencephalic lesions and behavior in cats: an analysis of the Klüver-Bucy syndrome with particular reference to normal and abnormal sexual behavior, *Journal of Comparative Neurology*, 108, 1957, 505–545.

[9] L. Weiskrantz, Behavioral changes associated with ablation of the amygdaloid complex in monkeys, *Journal of Comparative and Physiological Psychology*, 1956, 49, 381–394.

[10] F. Morrell and H. H. Jasper, Electrographic studies of the formation of temporary connections in the brain, *EEG and Clinical Neurophysiology*, 1956, 8, 201.

one of two kinds of symptoms that are produced by lesions in the limbic systems. A second kind of symptom appears as damage to the hierarchical relation between TOTE units. In order to execute a plan of any complexity at all it is necessary to keep track of where in the plan one has gotten. What happens when the hierarchical structure of TOTEs is disrupted is nicely illustrated by the behavior of a mother rat with limbic lesions. When a normal mother rat is faced with a situation in which her brood has been strewn around the cage, she will pick up one baby rat and carry it to the nest, go back to pick up another and return it to the nest, etc., until all the youngsters are safely back in the nest. This behavior does not appear when the mother has had a surgical operation to remove the cingulate cortex —another of the major subdivisions of the limbic systems. The surgically operated mother will pick up an infant, carry it part way to the nest, drop it in favor of another which may be carried to the nest only to be removed on subsequent trips. After half an hour of this the baby rats are still strewn all over the nest and, eventually, are left to die.[11] Similar disorganization occurs when these operated animals try to hoard food, an activity that is quite common among normal rodents when they become hungry.

A little can be surmised about how the hierarchical relation between TOTE units is accomplished in the nervous system. The amygdala seems to be necessary to the test phase of many innate TOTE units. Under normal conditions the electrical activity recorded from the amygdaloid complex changes only when the animal is startled or when, as a result of conditioning, his "attention" is focused on some environmental event. However, when the hippocampus—still another subdivision of the limbic systems—is inactivated by ablation or by massive electrical stimulation, the electrical activity recorded from the amygdala changes whenever the animal touches, or hears, or catches sight of *any* environmental event. It is tempting to speculate that the hippocampus normally protects the amygdala from all incoming information except that appropriate for the TOTE unit currently in control. The hippocampus could perform this "gating" function via the reticular formation in the internal core of the brain stem, which, in turn, is known to influence the receptors, the afferent pathways into the central nervous system, and the activities of the entire external portion of the forebrain. Thus the hippocampus may be intimately involved in the business of keeping the brain at work on the successive steps in the Plan and preventing it from being shunted haphazardly about by every fluctuation in the environment.[12] If so, it would fit very nicely into our conception of how the hierarchy of TOTEs (within the operational phases of their proto-TOTEs) can be established.

[11] J. S. Stamm, The function of the median cerebral cortex in maternal behavior of rats, *Journal of Comparative and Physiological Psychology*, 1955, 87, 77–88.

The frontal "association areas," sometimes referred to as "the organ of civilization," are intimately connected with the limbic systems to form the internal core of the forebrain. This most forward portion of the primate frontal lobe appears to us to serve as a "working memory" where Plans can be retained temporarily when they are being formed, or transformed, or executed. This speculation appears to be consistent with the fact that animals with lesions in the frontal lobes have difficulty with the delayed-reaction and the delayed-alternation tests. Both of these tasks require the animal to follow an internally stored Plan of action. The behavioral evidence is complicated, however, and it may well be that it is the transformation of Plans, rather than merely the storage of them, for which the frontal lobes are required.

The effects of frontal ablation or lobotomy on man are surprisingly subtle. Very few of the usual psychometric tests turn up any deficits at all. One that frequently shows a deficit is the Porteus maze, a pencil-and-paper labyrinth that would seem to require some planning. It should not be difficult to devise many more tests of planning ability and to use them on these patients. Clinical observations of their behavior would encourage us, at least in some cases, to expect that such tests would succeed in diagnosing the patient's difficulties. Such a patient is apt to "fall apart" when some minor detail goes awry in the Plan he is executing. If he is preparing dinner when the trouble occurs, he may not be readily capable of reshuffling the parts of the

[12] M. A. B. Brazier, ed., *The Central Nervous System and Behavior*, Transactions of the Second Conference, February 22–25, 1959, Josiah Macy, Jr., Foundation.

Plan. Segments of the Plan may simply be omitted—the vegetables are served raw—or the whole dinner may be lost. Even if these speculations prove to be wrong in detail, the notion that the frontal "association areas" are intimately linked to the limbic systems in the transformation and execution of Plans is worth pursuing. Clinical and laboratory observations that investigate *how* rather than *what* behavior is changed by the frontal lesions have hardly begun.

One fairly obvious consequence of looking at the relation of brain and behavior in the way proposed here is that we need a much more elaborate and precise theory than we have about an organism's Plans before we can predict what any particular lesion may do to him. Overly simple indicators, such as the strength, rate, or latency of some isolated movement pattern, will only delude us into thinking the processes are simpler than they really are. The ethologists are among the few students of behavior who have been willing to look for the Plan behind the actions and to describe it literally in the kind of flow diagrams that an engineer would need in order to construct a machine to perform the same functions. Given such a detailed specification of what is guiding the muscle twitches it may then be possible to see certain critical points at which the behavior can be disrupted by lesions in certain parts of the brain. To hope for relations between brain structures and crude, *ad hoc,* statistical indicants of some loosely defined abstraction called "response" is apt to be very misleading. The problem of specifying what constitutes a "stimulus" for an organism has long been recognized to be more difficult than it appears on the surface; the chapters in this book must make it equally clear that the mechanism that generates any "sequence of responses" may not be as simple as it may at first seem.

One of the most interesting aspects of brain function, therefore, is how Plans are constructed in the first place, how they are formed. The present discussion has been confined to the more limited task of describing how Plans must be executed. These speculations may throw some light on the functions of the limbic systems. But the authors are not sure where or how the brain might generate Plans. When a familiar Plan is remembered and only slightly modified to fit a new situation, we might find that its selection depended somehow upon the posterior "association areas" in the external portion of the

forebrain—selecting a Plan from memory is closely related to using the Image, and the Image, in turn, would seem to be mediated by the external portion. Perhaps the decision to execute a particular Plan is equivalent to transferring control from the posterior "association areas" to the frontal "association areas." Perhaps.

These speculations about the functions of the central nervous system take on a kind of finality and solidity when they are committed to paper that they did not have so long as they remained conversational. The authors know how fuzzy their own Image of this marvelous organ is and how oversimplified or arbitrary these statements must appear. Yet the notions of a reflex telephone system with an enigmatic switchboard, or inhibitions and excitations rippling majestically over the surface of the brain, or little homunculi inside the pineal glands of little homunculi inside the pineal glands of little homunculi *ad infinitum,* or empty black boxes that absorb *S*'s and emit *R*'s, are so thoroughly unsatisfactory that, although the present ideas may be wrong, they are likely to be a great deal less wrong than the metaphors many psychologists have used heretofore. Anybody who tries to do the research needed to put this approach to test will discover things that he would not otherwise have thought to look for.