Human software

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Just as the hardware of a large computer system requires a large program, often called software or an operating system (OS), to supervise and control its performance, so too do human beings require a mind to control the brain. Our OS, however, is hardwired in neuronal circuitry and also involves the endocrine system. Much evidence attests to the built-in nature and existence of our OS. Examples are our abilities (1) to conceive ideas, (2) to process them internally and symbolically, (3) to express them in any of several modes (e.g., as verbal strings, as visual images, in sign language, in body language), (4) to dream. Some of the probable anatomical components of the human OS are identified and some indications of its systematic effects on consciousness are discussed. Some research relating psychopathology to the OS is cited.

The ultimate goal of this work is to help to understand man's brain and mind. We are in a much better position to do this now than we have ever been before, because of the existence of computers. This is not to say that brains and computers work the same way either physically or chemically, because they do not. But just as a large computer system must have resident within it a large monitor program (called software)¹ that makes the hardware correctly perform the various calculations desired by the user, so too must our brains have a mind that arranges for the various components to do the right things at the right time. None of us really understands how it is possible to have an idea, generate a sentence, elaborate a dream, understand someone else's speech, store and retrieve memories, or perform any other of our many mental feats. But my contention is that, absolutely without question, there is an inherited ability² to structure, both simultaneously and sequentially, a multitude of parallel activities within various circuits in the brain. This ability is not something we learn for ourselves, nor are we taught how to do it. It is an emergent ability that develops and differentiates with time and practice. This ability I call "mind." It is itself embodied in hardware that at least in part includes the reticular and limbic systems and some portions of the frontal and temporal cortices.

In the computer, this software is often called an operating system (OS). It is usually a large program provided by the manufacturer. Because it is a program, it is possible to change instructions in it easily. In animals, including man, the "mind" = the "OS" is hard-

wired; that is, it is embodied in circuitry, most of which, probably, may never be changed. Some other portions may develop differently, depending on the individual and his circumstances, and it is not certain yet, but it may be that some portions of our OS may be changed with retraining.

One of the fundamental components of the mind according to psychoanalytic theory is the ego. This is generally considered to be merely a metaphorical structure that performs a number of intermediary functions between the id and the superego. It will be argued here that the ego definitely exists as a real structure and performs many of the functions that I attribute to the OS. The reason for introducing this computer terminology is that words like ego are too ambiguous, having been used by too many writers in not entirely consistent ways. The basic thrust of using the computer analogy is not to develop better computers but to help us understand our minds. We are now, since the advent of computers, able to speculate meaningfully about consciousness, memory, free will, the soul, and so on. These are concepts that have puzzled mankind for millennia. The existence of computers allows us to explore possible models of the necessary components and functional organization of the information handling and guidance systems that our brains and endocrine systems are.

HUMAN OVERVIEW

MacLean (1970) proposed that the mammalian brain be regarded as consisting of three principal components: the neocortex, paleocortex (limbic brain), and brain stem (Figure 1). Gazzaniga (1970) and Sperry (1961, 1966, 1974), in reporting work with split-brain animals and men provided evidence that man, too, is a multi-programming multiprocessor (see Appendix). Each hemisphere may be regarded as one processor, and within each hemisphere, there is the potential for three

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Figure 1. Diagrammatic representation of hierarchical organization of three basic brain types, which in evolution of the mammalian brain become part of man's inheritance. For purposes of discussion, they are labeled in ascending order as reptilian, paleomammalian, and neomammalian. The paleomammalian counterpart of man's brain corresponds to the limbic system, which is believed to play a special role in emotional functions. (After MacLean, 1970, with permission of the author and the Rockefeller University Press.)

levels of programming. Speech processing seems to be largely performed in the left hemisphere (Geschwind, 1972), whereas visual imagery is handled by the right (Bogen, 1969a, 1969b, 1969c, 1972), and there appears to be "no evidence . . . that one can think about more than one thing at a time" (Sternberg, 1969, p. 454). Therefore, using the "unconscious mind" to do some creative problem solving (Crane, 1960; Uhr, 1973, pp. 189-190) may be an instance of human multiprocessing.

In a multiprocessor configuration, each central processing unit (CPU) has its own schedule. Thus, it is conceivable that conflicts between these schedules might exemplify what psychiatrists refer to as "subconscious motivations." As for multiprogramming (i.e., within one CPU), the cerebral cortex, or "intellectual" brain, may have to yield to the limbic system, or "emotional" brain, when, for example, a student doing a problem at the chalkboard in class is insulted by being laughed at. There is thus obviously a need for an OS so that these various levels of activity may be properly managed in a person.

The true situation is undoubtedly much more complicated than is depicted in Blackmore (1975). In particular, it is probably more accurate to consider a model of the brain as being made up of at least two CPUs and two "attached" support processors (ASPs) (Katzan, 1973, p. 46; Ream, 1973, p. 195), as shown in Figure 2. Basically, such a system can operate as either a "dual" or a "duplexed" system (Katzan, 1973, pp. 359-360; Ream, 1973, p. 195; Yourdon, 1972, pp. 45-48). But

since in the adult the left and right hemispheres seem to be specialized for different tasks (Dimond & Beaumont, 1974), it is not clear how far we could operate in a truly "dual" mode. As a duplexed system, each component may do "its own thing." In many multiprocessing environments, the ASPs handle all communications with the external world and essentially are the masters, and the inherently more powerful CPUs are the slave computers. In our human systems, we may liken the ASPs to the two limbic systems and the two CPUs to the two cerebral cortices. The ASPs³ handle the emotions and short-term goal selection. They monitor the whole system's performance and feel elated or saddened by its successes or failures.

Actually, this master-slave relationship and the question of which component(s) is the boss probably change over time as the person grows. It is likely that the limbic system is dominant in the infant and toddler. But then, as the brain grows in size and as the extent of myelination increases, the cortex may assume control more frequently. However, most of us know, for instance, how difficult it can be to quit smoking or to stay on a diet, even though intellectually convinced on rational grounds of the importance of attaining each

Figure 2. Schematic diagram of a multiprogramming, multi-processor computer system. Each CPU is a large main-frame computer fully capable of standing alone but here hooked into a larger configuration. Each ASP (attached support processor) is a smaller machine and hence of lesser power than either CPU. In this configuration, however, one of the ASPs would be the home of the operating system (OS), which controls the whole installation. In that sense, therefore, the less powerful machine is the boss, or master, and the more powerful machine is the slave. The ASPs are basically responsible for communications both internally and externally.

goal. Thus it may be that the limbic (emotional) brain is prepotent compared with the intellectual brain in some persons even into supposedly mature adulthood.

It has been found necessary in the computer, when there are two or more CPUs, for there to be only one OS, to avoid possible internal conflicts. Generally, our mental systems are so structured that we will strive toward some goal(s). Not to have goals, and not to be able to strive toward them, often is both symptomatic and productive of mental illness. One of the principle themes of this article is that our brains are provided partly with a physical structure and partly with a chemical organization, such that, when both mentally and physically healthy, we are able to adopt goals and work toward them.

THE HUMAN OS: EVIDENCE FOR ITS EXISTENCE

The computer OS takes care of many functions that the user in consequence does not have to worry about. Thus input/output, storage and retrieval of data, updating files, and many other functions are all handled by software routines. In an analogous way, it is argued that we human beings must also have software to store and retrieve our memories, to compose motor programs, to have ideas, to construct sentences, and so on. We never learn how to do these acts, nor are we taught by any teacher, but at the appropriate time, assuming a healthy child, these abilities emerge. This is not to deny that schools perform necessary and useful functions, although, as all who have taught know, a teacher may be severely restricted by the caliber of the student.

There is no way to avoid the logically imperative requirement that the equivalent of an OS must exist in a human being. The various functions do not arise just from chance connections in the brain. As witness, Sperry (1975b, p. 31) reports the following: "The brain is not all that malleable, and the growth of nerve paths and nerve connections in the brain is anything but diffuse and non-selective. Neural circuits for behavior are definitely grown in, pre-functionally, under genetic control—and with great precision in an enormously complex, pre-programmed, biochemically controlled system."

Further evidence along these lines is provided by Hoyle (1975) for invertebrates, Kandel (1979) in the snail *Aplysia*, and Brodal (1975) in the human brain.

Development

Gesell—On development. Gesell (1952) establishes unequivocally that there is a sequence of physical, mental, and emotional developments in all healthy children that compels the inference that there must be inherited sets of programs and abilities that could only be orchestrated by some kind of biological OS. For example, Gesell (1952, p. 4) says, "Our objective approach to the study of the infant led in due course to certain conclusions: (a) The infant has a mind. (b) The infant comes by his mind as he comes by his body, that

is, through the organizing processes of growth. (c) He develops as a unitary action system. (d) This action system is manifested in patterns of behavior which are governed by deep-seated (ontogenetic) laws of developmental sequence."

Gesell defines six major principles in the growth process, only two of which will be mentioned here: (V) The principle of self-regulation. "He will learn only when he is developmentally ready. He will learn only what is appropriate to his state of readiness." (Gesell, 1952, p. 69). (VI) The principle of optimal realization. "Being the end product of ages of evolution the human action system is endowed with deeply entrenched growth potentials. Under normal or near normal conditions growth is irrepressible" (Gesell, 1952, p. 69).

Lenneberg—On language development. Lenneberg (1967, p. 375) says, "This basic capacity develops ontogenetically in the course of physical maturation; however, certain environmental conditions also must be present to make it possible for language to unfold. Maturation brings cognitive processes to a state that we may call language-readiness. The organism now requires certain raw materials from which it can shape building blocks for his own language development. The situation is somewhat analogous to the relationship between nourishment and growth. The food that the growing individual takes in as architectural raw material must be chemically broken down and reconstituted before it may enter the synthesis that produces tissues and organs. The information on how the organs are to be structured does not come in the food but is latent in the individual's own cellular components. The raw material for the individual's language synthesis is the language spoken by the adults surrounding the child. The presence of the raw material seems to function like a releaser for the developmental language synthesizing process. The course of language-unfolding is quite strictly prescribed through the unique maturational path traversed by cognition."

Piaget—On cognitive development. During the past 50 years, Piaget (Piaget & Inhelder, 1969) has done valuable research on the problem of emerging cognitive capabilities. Milner (1967) has attempted to relate the brain's progressive physical development to the developmental sequence proposed by Piaget. According to Piaget, as the child grows, the "sensorimotor" stage of thinking (ages 0-2 years) is overlaid by a "preoperational" stage (ages 2-7 years), which, in turn, is overlaid by a "concrete operational" stage, until finally, about ages 12-15 years, the "formal operational" or "propositional" level comes forth. Piaget acknowledges that the particular age ranges may not be rigidly adhered to, but he postulates an unchangeable sequence of stages in the intellectual development of the child and adolescent. He argues that the thought processes available to the "operational" thinking of the 7-12-year-old simply are not possible for the less than 2-year-old infant in the sensorimotor stage. And similarly, an adolescent in the "formal" stage is capable of adult thought that the

"preoperational" 2-to-6-year-old will not be able to understand himself for perhaps another decade.

There is evidence (Arons, 1976; Renner, 1976) that not all university students have necessarily completed the transition from the "operational" to the "propositional" level by their late teens or early 20s. On the other hand, Stanley (1974) discusses intellectually precocious youths who evidently were at the "formal" level of thought even before entering their teens. Others also have been concerned with these problems. For instance, Vygotsky (1934/1962) studied the progression of levels and kinds of thinking exhibited by healthy children, adolescents, adults, and some mentally ill patients. He found that only during adolescence (about ages 14-16 years) did truly conceptual thinking emerge. Before that age, the style of thinking was different, and Vygotsky referred to it as thinking using "complexes" rather than true "concepts." The thinking styles of psychotics were similar to those of young children.

The existence of and usefulness of postulating a Piagetian sequence of stages is not universally accepted (Brainerd, 1978). As regards the chicken-and-egg question of whether the brain development must take place first, Milner (1967, pp. 170-171) says, "Where the neural evidence indicates continued functional immaturity of neural tissue known or believed to be enabling of a particular category of behavior which has not yet emerged at the age observed, then it is tenable to assume that continuing maturation of such tissue is prerequisite to the eventual emergence of that behavior."

Further evidence of the importance of the built-in circuitry is provided by Rimland (1978) in describing 531 autistic-savant children in a register of 5,400 autistic children maintained by the Institute for Child Behavior Research in San Diego. Each autistic-savant child had at least one highly developed special ability notwithstanding the autism. The areas of these special skills were music, memory, art, pseudoverbal, mathematics, mechanical, coordination, directions, paths, and so on, calendar calculation, and extrasensory perception.

The most frequently occurring skill was in music, with the children usually capable of (although not limited to) an exceptional auditory memory. Three separate cases, as reported by their parents, will be quoted as examples: (1) "Can play anything he hears once on a piano or any instrument with keys, has perfect pitch." (2) "First noted musical and photographic (memory) ability at age two. With 'tape recorder' accuracy, she would explode from her silence with a total song with words—long verses—pages read, etc." (3) She can sing any note you tell her to and can tell what note (and key) is being played. Ilene woke up singing as an infant and never let up. Ilene knows practically every song ever written—who wrote it, what show it is from (or film), who first recorded it, in what year it was popular, etc. She also has a large command of the classical repertoire. She composes at the piano and has taught herself to play the guitar as one would play a zither."

Children with idiot-savant capability in music often demonstrated this by age 2 and fully two-thirds had done so by age 4. The peak of musical ability was reached by age 7 by two-thirds of the children in this category.

The hypothesis that these emergent abilities are genetically determined is difficult to reject, for the following reasons: (1) The abilities often emerge very early, long before any schooling, and to the amazement of the parents. (2) The nature of the skill (e.g., calendar calculations) is often such that the parent herself/himself does not know how to do it. (3) The "autistic" portion of the label is usually applied because of troubles that start to appear in the first few months after birth and are confirmed by others that emerge as the infant develops further (Cohen, Caparulo, & Shaywitz, 1978).

There is no doubt that genetic effects can predominate over social and cultural contributions to development. Examples are diseases such as phenylketonuria, galactosemia, Down's syndrome, and Huntington's chorea (Kety, 1979). This last disease (Freedman, Kaplan, & Sadock, 1975, pp. 91, 235, 1089) has piteous effects. It is transmitted by a single dominant gene, and hence, each child of an affected parent has a 50:50 chance of developing the disease. Unfortunately, it does not appear usually until the victim is between 30 and 50 years old, by which time most of his/her children have been born. The disease begins insidiously, but is progressive and unrelenting. Symptoms include a stumbling walk and paroxysmal writhing movements of the face, extremities, and upper body. Drooling and speech difficulties, dementia, and loss of judgment appear and then grow. Hallucinations and paranoid delusions are common. Death results about 15 years after the symptoms first emerge. Autopsy shows gross atrophy of the caudate nucleus and putamen and degeneration in the frontal cortex.

But now we turn to evidence that is closer to the main argument that mind must exist.

Ego

Spitz—On the developing ego. Spitz (1959) provides convincing evidence and arguments to support the view that there is a standard pattern of emergence of various behaviors that compels us to infer the existence of a psychic structure.

Thus Spitz (1959) cites the emergence of (1) the smiling response, at 3 ± 2 months, (2) the 8-month anxiety or fear of strangers, at 8 ± 2 months, and (3) the acquisition of speech, at about 18 months, as evidence supporting the inference that a psychic structure exists. Furthermore, in my view, internal preparatory changes must have been going on underground, presumably in the brain structure and organization, but beneath the superficially observable behaviors active at the time, in order for those emergent behaviors to blossom at their appointed times. (Also see Lashley, 1951).

In speaking of the smiling response, Spitz (1959, pp. 23-24) says, "It is stimulus specific, it is reliable and

it is volitionally directed. Let us recapitulate what this implies in the way of organization: (1) The infant turns from inner sensation to outer perception. . . . (2) Reality testing begins. (3) Memory traces are laid down and become available. (4) Directed object relations take their inception and can be observed.

"These are experimentally demonstrable and readily observable facts. If we look at these facts from the point of view of what I have called the systematic propositions of psychoanalysis, we can consider them as manifestations of: (a) The topographic division of the psychic apparatus into a conscious and an unconscious part. (b) The establishment of a differentiation of an ego and of an id from the stage of non-differentiation; in other words, the establishment of psychic structure. (c) As the first example of the functioning of thought process which in Freud's hypothesis consists in the displacement of cathexis along memory traces.

"All of this adds up to the picture of a far reaching organization, a process of crystallization in the psyche. A variety of discrete components, some of them maturational, some developmental (that is, specifically psychological) have been integrated and will from here on operate more or less as a unit."

To summarize Spitz' (1959) position briefly, we have the following: "The first of the organizers of the psyche (the smiling response) structures perception and establishes the beginning of the ego. The second (anxiety) integrates object relations with the drives and establishes the ego as an organized psychic structure with a variety of systems, apparatuses and functions. The third organizer (speech) finally opens the road for the development of object relations on the human pattern, that is, the pattern of semantic communication. This makes possible both the emergence of the self and the beginning of social relations on the human level" (p. 96).

More recent ideas about ego. The concept of the ego has undergone many changes during the past 80 years (Hartmann, 1964; Klein, 1976, pp. 121-160), and Klein discusses the difficulties faced by the several schools of thought as to the proper functions to be ascribed to it. Earlier, the ego was thought to intercede between the id and the superego, but in the new ego psychology, "the ego is established as the prime—in fact, only—regulative system of the psychic apparatus to which the claims of drives (id) and of superego are subordinated" (Klein, 1976, p. 144).

The ego is postulated to consist of a set of functions that performs many essential tasks. These tasks are similar to, but more extensive than, those of the computer OS. The ego is seen partly as working to resolve conflicts between itself and the id, between the superego and the id, and so on, but also to handle many routine mental housekeeping needs, such as updating files, storing and retrieving memories, and so on. Space does not permit an extended treatment of these questions here. But fundamentally, we are presented empirically with the facts that (1) in the computer world, an OS

has been found to be essential to the proper functioning of the system, and (2) in the psychiatric world, the concept of an ego that serves the person in a way similar to an OS has also been recognized by all investigators who have tried to understand the puzzle of man. (Ego functions obviously are mandatory in animals other than man too, see Hallowell, 1960.)

Sleep and Dreams

The two functions sleeping and dreaming are among the strongest pieces of evidence we have that an OS exists in everyone. We all sleep and dream every night, all our lives, without being trained how to do either. As is well-known, sleep occurs in physiologically distinguishable states (Arkin, Antrobus, & Ellman, 1978, pp. 10-16). Two commonly used categories are slow-wave sleep (SWS; often also called non-rapid eye movement, NREM, sleep) and paradoxical sleep (PS; also called rapid eye movement, REM, sleep). Although initially dreaming was considered only to occur in REM sleep, and a more "thought-like" mentation in the NREM state, it is now generally accepted that dreams may be reported on being awakened from either state (Broughton, 1975; Herman, Ellman, & Roffwarg, 1978).

In SWS, the major muscles have some tone, the cortical EEG exhibits high-voltage slow waves and REMs are absent. In PS, the major muscles have no tone, the cortical EEG exhibits low voltage, and fast waves and REMs are present, as are ponto-geniculo-occipital (PGO) spikes. There is evidence (Jouvet, 1967a, 1972, 1975) that serotonergic neurons of the rostral raphe system are heavily involved in sleep induction and that SWS is a necessary prelude to PS. However, two other conditions must also be satisfied in order for PS to appear. The first has to do with the waking system. Should this be activated during the latter portion of SWS before the expected appearance of PS, then PS will not appear. The second necessary condition is a cholinergic mechanism that interacts in an as yet unknown way with the serotonergic system (Jouvet, 1975). (The overwhelming complexity of the neurochemistry and circuitry in these areas of the brain stem are well documented by Morgane and Stern, 1974.)

Paradoxical sleep. In this state, there is an "intense endogenous phasic and synchronous activity of most cerebral neurons, including the pyramidal and extra-pyramidal motoneurons. . . . [This activity] implies the necessity of a cerebral 'pacemaker' and also . . . mechanisms . . . [to] inhibit . . . motor output" (Jouvet, 1975, p. 507). The pacemaker is provisionally located in the caudal two-thirds of the locus coeruleus (Morgane & Stern, 1974, p. 69), in which cells are mostly noradrenergic. This bilateral pacemaker is intimately associated with the production of PGO spikes, which, in turn, are intimately related to the REMs that occur during PS. It appears further that this central phasic electrical activity is not confined solely to the visual system (cf. Pivik, 1978) but also involves many motoneurons in the

pyramidal and extrapyramidal systems and the red nucleus and vestibular nuclei (Jouvet, 1975). This further implies the existence of a mechanism to inhibit the motor outputs (excluding the oculomotor system) that could otherwise produce major motor actions.

In order to show explicitly what these motor effects might be, Jouvet (1975, p. 511) described the results of destroying these specifically inhibitory neurons. "After such a lesion the cats, which have normal behavior either when awake or during slow wave sleep, enter into a most dramatic stereotyped 'pseudo-hallucinatory' behavior at the time when they would normally enter into PS They suddenly stand up, leap, and either display some aggressive behavior or play with their front paws as they might play with a mouse, or they show a rage behavior or a defense reaction against a larger predator During these episodes, even during the most intense rage behavior the nictitating membranes are relaxed and almost completely cover the pupils which are myotic. Thus, there exists a striking contrast between the motor behavior of rage and emotion and the vegetative ocular aspects of deep sleep. During these episodes the animals do not react to visual stimuli and they often collide with the walls of the observation cage. Normally these episodes last for 4 to 5 minutes (which is the average time of a PS episode). At the end, the animals either suddenly awaken . . . or return to a posture of quiet sleep. . . .

"These episodes are accompanied by the same central activity that distinguishes paradoxical sleep and are suppressed by the same drugs which suppress PS (MAO inhibitors). . . .

"If it is admitted that this stereotyped behavior is the result of the excitation of the pyramidal and extrapyramidal systems through the direct or indirect control of the pontine pacemaker, then we should admit that this behavior is organized. It is not like an epileptic discharge. We should also admit that such behavior is programmed and that it may express some teleological project and possibly some instinct."

Jouvet (1975) then makes the point that in the wild, this dreaming state renders the animal vulnerable to predators, and hence, in nature, PS may not be entered directly from the waking state. The SWS state that precedes PS is therefore "the guardian of dreaming and, contrary to Freud's writings, dreaming is not the guardian of sleep" (Jouvet, 1975, p. 515).

Now, to support the main theme of this article, some features about sleep and dreaming should be noted: (1) Although there was little PS in the birds studied (Jouvet, 1967a, 1967b) and none in the reptiles, all the mammals studied exhibited some PS, with usually more in the very young than in the adult animal. (2) Each kind of mammal is compelled by its own system to experience its characteristic amounts of time in SWS and PS every nycthemeron (omitting questions about hibernation). (3) PS may not be as imperative a requirement as SWS (Horne, 1978). (4) Although it may be

argued by some that Jouvet's (1975) illustration of oneiric activity in cats is not proof of true dreaming in animals other than man, we will agree that at least humans dream and that we do not choose to do this but are put through these paces each night by the neuronal systems in our mid- and hindbrains. During sleep, we are also subjected to changing hormonal tides (Broughton, 1974; Luce, 1971), which themselves presumably have been produced by the endocrine glands in response to changing signals from the pituitary and, ultimately, the hypothalamus.

Thus in a sleeping person, the OS is in command and induces different states of consciousness by operating partly through hard-wired circuitry, using particular neurotransmitters, and partly through hormonal controls. Consciousness during sleep onset (Vogel, 1978; Vogel, Foulkes, & Trosman, 1966) and during REM and NREM sleep differs in a number of ways from ordinary consciousness (Herman et al., 1978; D. G. Schwartz, Weinstein, & Arkin, 1978; Tart, 1975). Although there is a massive literature on dreams, no attempt will be made to review that here. But I will try to bring out some of what seems to me to be the central features of dreams and dreaming.

First, as summarized by Dell (1975) and as mentioned by Jouvet (1975, p. 514), in REM sleep, the sensory systems have increased thresholds to signals from the outside world. Furthermore, during the REM episodes, either the PGO spikes or some other concurrent neuronal activities compel us to hallucinate (dream), usually in visual and auditory images. The contents of some sleep-laboratory dreams have been reported by Snyder (1970). Thousands of dream reports by people of all ages, many cultures, and both sexes have been collected by Hall and Nordby (1972) and Hall and Van de Castle (1966). Many dreams depict some easily intelligible scene, action, or mood. In others, symbols are used to represent some of the ideas, persons, characters, actions, moods, and so on. Hall (1966, pp. 93-95) rejects Freud's hypothesis that symbols are used to disguise otherwise forbidden wishes, and so on. Instead, he argues cogently that the particular symbols used in each dream are the most efficient (succinct) and elegant (in the mathematical sense) way to represent the quintessence of the dreaming psyche's conceptions. As Hall (1966, p. 95) says, "Dreaming is a form of thinking and thinking consists of formulating conceptions or ideas. When one dreams, his conceptions are turned into pictures. The images of a dream are the concrete embodiments of the dreamer's thoughts; these images give visible expression to that which is invisible, namely, conceptions."

The following dream (which I dreamed many years ago while at another university) will illustrate the aptness and elegance of the spontaneously generated symbols. The dream: Colleague A and I were riding a bicycle built for two, picking up speed, and starting down a long hill, at the bottom of which stood a large

bull with big horns. I said to A (without fear, simply by way of comment), "Look out for that bull, he may knock us off the road." As we rode down the hill, a llama (the South American ruminant) was walking uphill by the side of the road.

The interpretation: Colleague A and I had proposed to the administration that we should offer jointly a new course in the upcoming year. One of the administrators (my opinion of whom was that he was full of bull) had offered some objections to the proposal. Another colleague, B, would not be sharing in the new course and, indeed, often made suggestions that ran counter (walking uphill) to ideas proposed by A and me. Furthermore, he was having some career difficulties at the time (an uphill struggle). Finally, B was an American (a land to the south), and his general attitude and facial expression were well portrayed by the llama's typical snooty look. Comment: I suspect that even if I had wished to depict that situation while awake I could not have produced as elegant a condensation of those ideas, with all their subtle implications.

The clinching pieces of evidence, in my view, for an OS are the following: (1) We are able, in the first place, to conceive the ideas that are portrayed in our dreams. (Remember, even 2-year-old children have been shown to dream; Kohler, Coddington, & Agnew, 1968.) (2) Our brains are able to generate symbolic representations that are astoundingly apt and often are simultaneously meaningful at several levels. This ability is possessed by each of us and is not just granted to outstanding geniuses. In a completely untutored, unsocialized, and unknown way, our brains are able to do this while we sleep. (3) We can understand and empathize with explanations offered by others for their dreams and symbols. This last point raises the whole question of language, which will be treated next.

Language

Lenneberg (1967, pp. 125-182) does an excellent job of analyzing the emergence and development of language in the child. He tested the emergence of language against four criteria to determine whether it could be considered to be maturationally controlled. The criteria were: "(1) regularity in the sequence of appearance of given milestones, all correlated with age and other concomitant development facts; (2) evidence that the opportunity for environmental stimulation remains relatively constant throughout development, but that the infant makes different use of such opportunities as he grows up [cf. "Gesell—On development," above]; (3) emergence of the behavior either in part or entirely, before it is of any immediate use to the individual; (4) evidence that the clumsy beginnings of all the behavior are not signs of goal-directed practice" (Lenneberg, 1967, p. 126).

Lenneberg (1967, pp. 128-130) provides a table showing the parallel maturation of motor and language skills. This table persuasively suggests how the emergent

sequence of behavior patterns must be dependent upon prior appropriate neuronal developments.

Even more striking evidence of the built-in nature of language ability is presented by Lenneberg (1967, p. 146): "If aphasia strikes the very young during or immediately after the age at which language is acquired (between 20 to 36 months of age), the recovery is yet different. Cerebral trauma to the two or three year old will render the patient totally unresponsive, sometimes for weeks at a time; when he becomes cognizant of his environment again, it becomes clear that whatever beginning he had made in language before the disease is totally lost, but soon he will start again on the road toward language acquisition, traversing all stages of infant vocalization, perhaps at a slightly faster pace, beginning with babbling, single words, primitive two-word phrases, etc., until perfect speech is achieved."

The emphasis, in this paper, placed on the necessity of prior relevant neuronal development is not intended to deny the importance to the child of actively engaging in communication with others (cf. "Lenneberg—On language development," above). It is well-known that a child must participate in and practice a language to acquire it; simply to hear a language spoken is not enough. Thus Moskowitz (1978) mentions the case of a boy with normal hearing whose deaf parents (and their friends) used American Sign Language (ASL) in the home. The TV set was left on, in the hope that the child thereby would learn English. By age 3 he was fluent in ASL but did not understand or speak English at all. Also, although congenitally deaf infants have been heard to babble and coo initially, this usually stops by about 6 months of age.

Moskowitz (1978, p. 94B) points out that "children are fairly impervious to the correction of their language by adults, indeed to any attempts to teach them language." Also (p. 94D), "It seems to be virtually impossible to speed up the language-learning process. Experiments conducted by Russian investigators show that it is extremely difficult to teach children a detail of language more than a few days before they would learn it themselves."

In an attempt to illustrate the vital importance for language ability of built-in prior neuronal developments over any contribution from the social environment, the parallel with the development of vision will be discussed. Not only does this allow evidence to be adduced from experiments with other animals, but also vision is a faculty that is generally conceded not to be socially taught, although there certainly is an environmental contribution. The material below draws heavily on Hirsch and Jacobson (1975).

First, Hirsch and Jacobson (1975) distinguish two major categories of neurons in the developing brain. The first kind, the "invariant" neurons, are such that the shapes of the cell bodies, their locations in the neuronal network, and their connections with other "invariant" cell bodies, even connections with specific

locations on specific dendrites, seem to be laid down genetically. The second kind, the "variable" neurons, are contained in the "invariant" network, and their presence or absence, shapes, and interconnections are not as reliable or predictable. Hirsch and Jacobson then describe "macroneurons," or Golgi Type I neurons, which are the large, principal neurons in each region of the brain. These arise earliest in the embryo and develop largely independently of the environment. The "microneurons," or Golgi Type II neurons, originate later, often postnatally, when the environment does have a say. It is these microneurons that are postulated to provide the modifiability in behavior that is known to occur. (The reader is strongly urged to consult Hirsch and Jacobson, 1975, for the complete description.)

Hirsch and Jacobson (1975) divide the process of the histogenesis and morphogenesis of the nervous system into five stages: proliferation, migration, differentiation, growth, and cell death. After a young macroneuron cell has migrated to its proper location, it differentiates and puts out an axon and dendrites. Its axon joins with those of other macroneurons to form nerve-fiber tracts that establish the structural invariance of the network. Neuroanatomists are able to recognize hundreds of different types of cells, each of which forms into particular patterns in particular areas of the brain. Microneurons also have identifiable features, although they are not as predictable as the macroneurons and seem to branch in a more random fashion. During the course of proliferation and migration, a tremendous excess of neurons is produced. Then a selective weeding is thought to take place (this is extremely difficult to establish experimentally). It is postulated that activity along a particular pathway ensures the survival of that circuit, whereas never-used circuits wither and die before the animal reaches adulthood. This is thought to be the way the environment fixes some circuits but not others in the neuronal network.

"This validation of tentative connections would have to occur at the appropriate stage of development so it must be governed by an appropriate, presumably genetically controlled, timetable. In the case of mammals, for example, selection of the appropriate connections from among the excess that had been created would have to be delayed until the animal is first exposed to the external environment. One would, therefore, expect environmental factors to have their effect on the developing nervous system during some 'critical period'" (Hirsch & Jacobson, 1975, p. 118).

Hirsch and Jacobson (1975) then cite evidence to show that sensory stimulation is necessary for the development of normal vision in the cat. By raising kittens under carefully controlled conditions of light and dark, with their eyes exposed to patterned and non-patterned environments, scientists were able to show significant differences in the arrangements of living neurons in the visual cortex. There is evidence in the

human, too, that the organization of the visual pathways may be altered by early visual experience (Freeman & Thibos, 1973).

To summarize and generalize from the paper by Hirsch and Jacobson (1975), we have the following (and remember that inaccuracies are inevitable because of the oversimplification): (1) There is a definite genetically determined structure or organization of the macroneurons in each area of the brain. (2) The accompanying microneurons appear later, are more variable, and may be the means whereby the environment has an impact on the inherited structure. (3) This environmental impact is probably largely confined to a "critical period." (4) The specific neuron populations in each animal must "experience," or actually participate in, the relevant activities in order to become a properly functioning network (Held & Hein, 1963).

Now we return to the question of language development. It is obviously not possible to do experiments with language development in children similar to those done on vision in kittens. But presumably, there is a similar development of macro- and microneurons in the brain areas involved with language. Certainly, much evidence exists that there is a standard development pattern for language ability in children all over the world (Brown, 1965, 1970; Lenneberg, 1967; Moskowitz, 1978). For instance, Moskowitz (1978, p. 92) says, "Most children have completed the greater part of the basic language-acquisition process by the age of five. By that time a child will have dissected the language into its minimal separable units of sound and meaning; . . . [he] will have discovered the rules for recombining sounds into words, the meaning of individual words and the rules for recombining words into meaningful sentences and . . . will have internalized the intricate patterns of taking turns in dialogue." It is also clear that there is in us an instinctive drive to speak. It is known that particular areas of the brain are involved in language, such as Broca's area, Wernicke's area, the angular gyrus, and so on (Arbib & Caplan, 1979; Geschwind, 1972, 1974, 1979; Zurif, 1980). On the other hand, it has been pointed out often (e.g., Lenneberg, 1967, pp. 52-72; Luria, 1970, 1973, 1975) that the brain is highly interconnected and that, usually, it is not possible to identify precisely which element(s) of a complicated activity is performed in a particular location.

Nonetheless, work done with radioisotopes in the cerebral bloodstream (Lassen, Ingvar, & Skinhoj, 1978) to measure above average activity in local areas of the cortex in response to active demands on the patient to perform specific tasks has clearly demonstrated how different areas switch in or out to handle particular tasks (e.g., reading aloud vs. reading silently).

It is as though the various identified areas are micro-processors specializing in their own particular tasks and being orchestrated by the frontal lobes in the overall job. In discussing the question of serial order in behavior,

Lashley (1951) argued cogently for the necessity of an OS (although, of course, he did not use that term). He said, "The problems raised by the organization of language seem to me to be characteristic of almost all other cerebral activity. There is a series of hierarchies of organization; the order of vocal movements in pronouncing the word, the order of words in the sentence, the order of sentences in the paragraph, the rational order of paragraphs in a discourse. Not only speech, but all skilled acts seem to involve the same problems of serial ordering" (Lashley, 1951, p. 121).

Even stronger evidence for the existence of a built-in OS is the fundamental but unlearned ability to generate and work with ideas. Nobody knows how the brain does this. Presumably, the brain is able to handle subunits of ideas [which we may call idemes, by analogy with the phonemes and morphemes of speech and the cheremes (Klima & Bellugi, 1979, p. 40) of signs, as in ASL]. These idemes may be permuted and recombined to yield new ideas. The resultant ideas may then be contemplated internally or expressed in dreams, words (written or spoken), signs (as in ASL), or paintings and drawings. (The questions of expressing ideas in dance, music, body language, and so on will be omitted for now.) Thus we have all, so to speak, stood around with our noses pressed against the window of the internal computer room waiting for the processing to be done and the output to be provided by the biological OS in a form appropriate to the circumstances. It is certain that we are not taught how to do this. The abilities emerge in due course, and our systems use raw materials from the environment as needed (cf. "Lenneberg—On language development," above). It is not possible to say much about the process in general, but one thing seems probable and another certain. It is probably true that the ultimate internal representation of sensory information is different from the actual input signals. (For instance, consider retinal inputs, proceeding to the lateral geniculate nucleus, the striate cortex, the visual association cortex, and, after data reduction, ultimately forward into the temporal or frontal lobes; Powell, 1973.)

The thing that is certain is that it is not necessary to use words to have or process all ideas. For example, dream imagery and the associated ideas were discussed earlier. Also, we can be confident that a chess master does not translate all the tentative combinations he conceives into words to evaluate his ongoing position and select his next move. And Lenneberg (1967, p. 362) unequivocally describes the great competence of young deaf children in imaginative play as follows: "They love make-believe games; they can build fantastic structures with blocks or out of boxes; they may set up electric trains and develop the necessary logic for setting switches and anticipating the behavior of the moving train around curves and over bridges. They love to look at pictures, and no degree of stylizing renders the pictorial representation incomprehensible for them, and their own drawings leave nothing to be desired when

compared with those produced by their hearing contemporaries. Thus, cognitive development as revealed through play seems to be no different from that which occurs in the presence of language development. On the other hand, and this is the second type of observation, mentally deficient children may have a much greater degree of language development at age five than the peripherally deaf, but here the language advantage does not help the level of sophistication for play."

As further evidence that words are not necessary to have ideas, Goldin-Meadow and Feldman (1977, p. 401) describe the experiences of several deaf children who had deliberately not been exposed to any manual language and yet who individually developed a "structured communication system that incorporates properties found in all child languages. They developed a lexicon of signs to refer to objects, people and actions, and they combined signs into phrases that express semantic relations in an ordered way." The children did this in the absence of "an explicit, conventional language model. This achievement is cast into bold relief by comparison with the meager linguistic achievements of chimpanzees." (And, not to denigrate chimpanzees, some more recent work by Savage-Rumbaugh, Rumbaugh, & Boysen, 1978, on linguistic exchanges between chimpanzees using computer terminals should be consulted.)

HARD-WIRED SOFTWARE

In the early days of the computer when core was expensive and memories were small, a common practice was to set up routines in hard-wired form. For instance, actual circuitry was often used to perform floating-point arithmetic, because to have software do it used up precious core. But as core became less expensive, the practice grew of using software routines to handle those tasks. However, in the biological world, it seems to be the case that software is hard-wired partly in neuronal circuitry and partly in the hormonal controls of the endocrine system. It must remain an open question for the moment as to whether some of our software may be modified by training.

Another question that needs to be mentioned is the problem of functional localization in the brain. Thus Geschwind (1972) argues that particular areas of the brain (e.g., Wernicke's area, Broca's area, etc.) are involved in the particular tasks of understanding and producing speech. And Luria (1975, pp. 339-346) reminds us forcefully that the brain is highly interconnected and that the localization line of argument can lead to major discrepancies with empirical facts.

As an illustration for the antilocalization argument, Oatley (1978, p. 35) cites Gregory's metaphor, which runs as follows: Suppose a capacitor in a radio receiver were to fail and a screeching wail poured forth. An unwarranted inference would be that the normal function of that capacitor was to be a "wail suppressor." Rather, so goes the argument, does this demonstrate the

need to consider the operation of the whole circuit, not just that of some component. But this metaphor hides the fact that radios, and amplifiers in general, are highly structured devices. Tubes or transistors are arranged in a sequence of stages, each of which performs quite specific operations on its input(s) before passing the modified signal on to the next stage. The upshot of the argument, finally, is that both camps are partly right. The brain is terribly close-packed, highly integrated, and tightly interrelated, but there is nonetheless both localization and specification. Strong indications of local specialization are provided by much empirical evidence collected over the past 100 years from the effects of strokes, epilepsy, mental diseases (both organic and functional), and so on. And certainly, the empirical evidence from much simpler animals is very strong for localization and specialization (e.g., Hoyle, 1975; Wells, 1978).

"Closed," "Open," and "Free" Programs

Mayr (1974) discusses how much of animal behavior is "instinctive" as opposed to "learned." He argues that behavior may be considered to be instinctive, or "closed," when it is genetically determined and when in its execution it does not require the incorporation of any environmental circumstances. As an example, he discusses the behavior of a freshly hatched drosophila female kept "in complete isolation until she is ready to mate and then [if one] offers her simultaneously a choice of males of several species including her own, all these males display to her, but she almost unerringly accepts the courtship only of the male of her own species" (Mayr, 1974, p. 651).

For "open" programs, however, although there is much that is determined genetically, there is also a contribution from the environment. One example that Mayr (1974) uses is "imprinting" in the greylag goose, in which "the freshly hatched chick will follow the first moving object making sounds and adopt it as parent and sometimes even as potential mate" (p. 652). Even with "open" programs, these animals are by no means "tabula rasa." Admittedly, some elements of what finally will be the operational program are picked up (imprinted) from the environment, but those elements are only a portion (often quite small) of the whole program. (Examples of both closed and open programs in many species are provided in Eibl-Eibesfeldt, 1975.)

In human beings, there are undoubtedly many "closed" programs, such as, to name only a few, how to suckle, swallow, sneeze, grasp, become angry, move arms and legs, walk, think, dream, and feel (sentiments: e.g., hate, love, pride, sadness).

We have also a vast number of "open" programs, such as whom to choose as a mate, when to become angry, which languages to speak, and which style of life to adopt (obviously, these lists could be greatly extended). There is a good technical discussion in E. H.

Hess (1973, chap. 6) of the possibilities of imprinting existing in human beings. Berne (1973, p. 255-257) accepts it as a valid basis for understanding certain facets of human behavior.

The third category, "free" programs, includes those that we program for ourselves, which are completely independent of any genetic structure. Thus, for instance, consider the paths that I may follow in driving from home to York University. This is a 12- to 15-mile trip, depending on the way I choose.

Thus it is incorrect to suppose either that we begin as "tabula rasa" or that we are provided only with "closed" programs. And obviously, too, our individual, unique bodies and brains impose limitations on what is ultimately possible for each of us.

What Might Be Our OS?

Probably the most easily understandable overview of the brain's organization is that suggested by MacLean (1973) and shown in Figure 1. We must bear in mind that the brain may be the most highly organized and intricate system in the world and that anything to be said about it must inevitably be a gross oversimplification and, therefore, almost inevitably incorrect. MacLean's reptilian brain, as the most ancient, is probably the source of the instincts and drives. This is supplemented and extended by the paleomammalian brain, which MacLean has identified with the limbic system and which is frequently referred to as the emotional brain. Finally, there is the neomammalian or cognitive brain, reaching its zenith (as we humans like to believe) in man.

In the psychoanalytic model of id, ego, and superego, it perhaps does least injustice to these concepts to think of the id as largely embodied in the reptilian brain. But the ego must be part of all three brains, reptilian, paleomammalian, and neomammalian. There had to be a rudimentary form of ego far down the phylogenetic scale, for whenever switching had to be done from one set of programs to another and whenever memories had to be stored and retrieved, at least those ego functions had to be available. Thus, for instance, there must have been an early OS in the octopus, long before vertebrates arrived on the scene (cf. Wells, 1962, 1978).

Luria (1973) provides a detailed argument, together with supporting references to show that the prefrontal lobes, parts of the limbic system, and down into the reticular system perform many of the functions attributed here to the ego or an OS.

Thus, Luria (1973) says, "The tertiary portions of the frontal lobes are in fact a superstructure above all other parts of the cerebral cortex, . . . they perform a . . . universal function of general regulation of behavior" (p. 89). "Destruction of the prefrontal cortex leads to a profound disturbance of complex behavioral programs and to a marked disinhibition of immediate responses to irrelevant stimuli, thus making the perfor-

mance of complex behavioral programs impossible" (p. 91). "The frontal cortex participates in the generation of activation processes which arise as the result of the most complex forms of conscious activity and are effected with the immediate participation of speech. . . . These parts of the cerebral cortex . . . are particularly rich in connections with the descending activating reticular formation and they demonstrate that the frontal lobes in man participate directly in the state of increased activation which accompanies all forms of conscious activity. They also suggest that it is the prefrontal zones of the cortex which evoke this activation" (p. 94).

Nauta and Feirtag (1979) and Nauta and Karten (1970) also present anatomical evidence to support the view that the reticular system, parts of the limbic system, and parts of the prefrontal lobes literally embody parts of our OS. Thus, for instance, Nauta and Karten (1970, p. 10) say, "The intrinsic function that most typifies the more rostral parts of the brain, and especially the forebrain, appears to lie in the perception of goals and goal priorities as well as in the patterning of behavior strategies serving the pursuit of these goals (stability in time, or stability of goal-directed behavior." And Nauta (1971, pp. 181-182) says, "Frontal cortex [is] in a reciprocal relationship with two great functional realms, namely: (1) parietal and temporal regions of the cerebral cortex involved in the processing of visual, auditory and somatic sensory information, and (2) the telencephalic limbic system and its subcortical correspondents, in particular the hypothalamus and meso- and diencephalic structures associated with the hypothalamus. The reciprocal nature of both of these two relationships deserves particular emphasis, for it entails a need to view the frontal lobe at once as a 'sensory' and as an 'effector' mechanism. . . . The frontal lobe is characterized so distinctly by its multiple associations with the limbic system and in particular by its direct connections with the hypothalamus, that it would seem justified to view the frontal cortex as the major—although not the only—neocortical representative of the limbic system. The reciprocity in the anatomical relationship suggests that the frontal cortex both monitors and modulates limbic mechanisms."

It will come as no surprise to readers of this journal that parts of the brain must be used to plan and to organize, supervise, and control other parts of the brain. When we consider the incredible complexity of the brain, it is difficult to imagine that man ever thought all the necessary connections just grew by chance. The "tabula rasa" concept is so ridiculous it is hard to believe it could ever have been given serious attention (cf. Sperry, 1975a).

STATES OF CONSCIOUSNESS

Before the OS may be considered further, we must discuss consciousness briefly. The brain and mind are much more complicated than any existing computer

and OS. The brain operates in different states of consciousness as a function of different degrees of availability of various neurotransmitters in various tracts, of different concentrations of hormones and other biochemicals in the bloodstream, of different concentrations of solutes in the cerebrospinal fluid (CSF), and of different psychological environments, to mention only some of the possible factors.

To the best of my knowledge, no satisfactory understanding or definition of consciousness exists, although many persons have tackled the problem and many books and articles have been written about it (e.g., Davidson, 1976; Globus, Maxwell, & Savodnik, 1976; G. E. Schwartz & Shapiro, 1976-1978; Tart, 1975).

Tart (1974) suggests that each state of consciousness has associated with it a set of attributes and abilities such that some states allow the individual to do much less than others (e.g., when feeling dull, leaden, and heavy, it is not physically possible to be as witty and clever as in an "excited" state). We might say that in each state, only a subset of all possible programs is available to be used. Thus, in a coma, the program(s) that allow breathing and swallowing may be available although the individual is not able to carry on a normal conversation. Again, in an ecstatic state (Davidson, 1976), the person might be so entranced by his experience as not to wish to or not to be able to descend to the level of ordinary talk. There are also reports (Mostert, 1975) that some patients may achieve states of consciousness in which they remember the contents of conversations that took place in the operating room while they were anesthetized.

Schmale (1973) argues that there is a continuous spiraling through introvert-extrovert states of consciousness on a 90-min cycle, day and night. Broughton (1975) discusses a left-right alternation between hemispheres on the 90- to 100-min basic rest-activity cycle, with a corresponding alternation between neutral activity of a thought-like vs. fantasy-like nature. Some states seem to be continuous with each other (e.g., dull → normal → alert → excited), but others demonstrate quite sharp discontinuities (e.g., SWS → PS, in which there is the sudden appearance of hallucinatory ability). Sargant (1974) discusses some abrupt transitions, as do Gellhorn and Kiely (1972). Gellhorn (1967) discusses the states of consciousness available to or produced by "tuning" the ergotropic or the trophotropic systems (cf. W. R. Hess, 1964). Basically, the ergotropic system is related to the sympathetic and the trophotropic to the parasympathetic autonomic nervous systems, but there are associated effects on the skeletal musculature and the activity of the cerebral cortex, as well.

Gellhorn and Kiely (1972, pp. 399-400) state, "The ergotropic syndrome consists of an increase in sympathetic discharges and in skeletal muscle tone and also of a diffuse cortical excitation (desynchronization of EEG potentials as in awakening). The trophotropic

syndrome is associated with increased parasympathetic discharges, relaxation of skeletal muscles and lessened cortical excitation (increased synchrony as in sleep). It has been recognized in the unanesthetized animal that steady increase in the ergotropic-trophotropic ratio brings about behavior changes from deep sleep to wakefulness and finally to emotional excitement." Meditation also allows one to alter one's state of consciousness (Davidson, 1976; Fischer, 1971; Pagano, Rose, Stivers, & Warnenburg, 1976).

The existence of two counterpoised limbic systems and the behavioral effects to be expected from each has been discussed by Livingston (1973). He described the effects of lesions and irritative disturbances in both the "medial limbic circuit" (corresponding mostly to the trophotropic system) and the "lateral limbic circuit" (corresponding to the ergotropic system). Livingston (1973, p. 1892) says, for example, "There is clear evidence of the time-locked association of episodes of aggressive behavior with seizure discharge spreading from the amygdala, evidence that abrupt mood change can be induced by stimulation of the amygdala. Gellhorn and Kiely (1972, p. 400) also discuss how it is possible to alter the trophotropic-ergotropic balance in two different ways: "(1) by directly stimulating the 'centers' of the ergotropic or the trophotropic systems in the hypothalamus or other cerebral areas; and (2) by indirectly altering the activity of the ergotropic and trophotropic systems. This may be accomplished through the cerebral cortex or by changing the degree of afferent discharges impinging on the hypothalamus and reticular formation. It has been shown in particular that proprioceptive impulses are very effective in this respect. Reduction of proprioception through curare-like drugs greatly reduces the ergotropic responsiveness of the hypothalamus and diminishes hypothalamic-cortical discharges."

It is precisely this kind of abrupt transfer of control to different programs (as mentioned by Livingston, 1973, when the amygdala is stimulated) and/or the shifting nature of the responses available from the person in compliance with the ergotropic-trophotropic balance that shows that we are working here with our human OS. This has to be part of our "mind." Lashley (1958, p. 4) says, for instance, "No activity of mind is ever conscious" and this is precisely what we would expect here. The individual has no idea of what needs to be done to switch his system, but the change is effected and he experiences different feelings that evoke different thoughts and make different behaviors possible. Conversely, different thoughts may induce different feelings and also result in switching the system (Davidson, 1976).

It seems reasonable to postulate that the hypothalamus-pituitary-endocrine system is involved in setting and maintaining the intermediate-term mood of the individual (Mason, 1974). The central nervous system (CNS) is relatively fast acting and handles the short-term responses, but the endocrine system, because

it acts through the relatively slow-moving bloodstream, can maintain a mood for minutes or even hours. The very long-term controls are probably mediated through the CNS again in the form of beliefs and attitudes that both are affected by and affect the innate temperament of the person (and hence, the basic ergotropic-trophotropic balance of the individual). It may also be true that the composition of the CSF has an effect on the person's mood and the responsivity of his CNS.

PSYCHOPATHOLOGY

In an important review paper, Livingston (1973) discussed the behavioral differences associated with changes in the medial and basolateral limbic circuits. The medial limbic circuit incorporates the septal nuclei, anterior thalamic nuclei, cingulate gyrus, hippocampal gyrus, mammillary bodies, and the limbic midbrain area of Nauta. This circuit is richly connected with the reticular system below and the limbic forebrain (medial-frontal cortex) above. Destructive lesions in the medial limbic circuit largely produce motor and psychic hypoactivity, whereas irritative lesions have the opposite effects, resulting in restlessness, anxiety, irritability, and obsessive-compulsive behavior. The basolateral limbic circuit involves the orbital cortex, dorsomedial thalamic nucleus, amygdala, and anterior temporal cortex. The orbital cortex is implicated in schizophrenia and depression, the amygdala in aggressive behavior, and the anterior temporal cortex in interpretive behavior integrating the sensations and emotions experienced by the subject in his ongoing life. In temporal lobe epilepsy, the auras often involve olfactory-gustatory-alimentary sensations, as well as unpleasant emotions such as loneliness, detachment, fear, and confusion. Other organic trauma in the anterior temporal lobes are also known to produce acute disturbances of perception, hallucinations, and delusions.

Flor-Henry (1978) further extended the above line of thought to explore how the orbital frontal-anterior temporal systems might be implicated in the schizophrenic syndrome, the affective psychoses, and the atypical psychoses. Flor-Henry used a battery of neuropsychological tests to study (with L. T. Yeudall) 114 consecutive patients with schizophrenia, manic-depressive psychoses, and periodic schizoaffective psychoses and was able to draw a number of significant conclusions, partly summarized by Flor-Henry (1978, pp. 396-397): "The schizophrenic syndrome is determined by neuronal disorganization of the dominant fronto-temporal limbic regions. It may, of course, emerge with bilateral fronto-temporal perturbation. It may also result from lesions in the mesencephalic limbic core, the medial forebrain bundle, or the striate, particularly in the caudate regions, if these evoke lateralized projected changes impinging on the dominant temporal limbic cortex. The manic-depressive syndromes hinge on asymmetrical dysfunction of the orbital-frontal-non-dominant fronto-

temporal axis. At a certain intensity of depression contralateral neurophysiological disorganization of the dominant fronto-temporal systems may be induced. This in turn modulates the schizo-affective syndromes and also perhaps, with a more anterior gradient, the manic phase of the bi-polar psychoses, in which verbal disinhibition is so prominent. . . . [W]hen catatonic or affective admixture supervenes in schizophrenia the neuronal disorganization in the dominant temporal limbic system has extended into the orbital-frontal mood systems and in the mesial-frontal supplementary motor systems."

Much evidence exists (Bleuler, 1950; Bowers, 1974; Burnham, Gladstone, & Gibson, 1969; Hill, 1955) to support the view that schizophrenia is a disease (or group of diseases) of the ego (Federn, 1952a, 1952b) or OS. For example, there may be extreme indecisiveness as to what to do, and inappropriate affect coupled with inability to persevere toward a goal. On the other hand, there may be perceptual difficulties and inability to control attention (McGhie, 1973; Silverman, 1969). Bowers (1974) reports details from many cases of acute psychosis from both the foregoing points of view. Many illustrations are provided of patients' facing developmental problems in the courses of their lives, falling into states of severe anxiety, and experiencing radically altered sensations and perceptions (amounting to hallucinations and delusions in many cases) along with altered states of consciousness. Not only may there be an extremely heightened sense of awareness, but also there may be feelings that the experiential self has been divided, invaded, taken over by others, and so on. Most of the troubles listed and implied above would, in a computer, be in the OS.

Other illustrations of malfunction in the human OS are provided by Oscar-Berman (1980). She reports on a decade of experimental work with patients with Korsakoff's syndrome and comparisons with patients having parkinsonism, Huntington's chorea, and various aphasias. It has not yet proved possible to disentangle precisely which anatomical structures are responsible for which functions, but certainly, the brain regions implicated and some of the OS functions involved are among those we have discussed in this paper. Thus Oscar-Berman (1980, p. 418) says, "It is likely that the multiplicity of deficits observed in alcoholic Korsakoff patients can be linked to the multiplicity of their sites of brain damage: frontal cortex, amygdala, and/or their connections for attentional deficits; frontal cortex, temporal cortex and/or their connections for perceptual retardation; hypothalamus, thalamus and/or amygdala for abnormal responsiveness to reward contingencies; temporal-lobe structures and/or frontal cortex for associative-learning deficits."

Yeudall (Note 1, Note 2) and Yeudall and Fromm-Auch (1979) report the results of using a neuropsychological battery of tests and quantitative EEG techniques to assess cerebral damage (brain dysfunction) in several

populations exhibiting aggressive behavior, persistent criminal behavior, psychiatric syndromes, delinquent behavior, alcoholism, and learning disabilities. Their results have consistently implicated dysfunction of the temporal and frontal brain systems. And it is precisely these systems that have been identified here as involved in the human OS.

SUMMARY

The main theme of this article is that mind must exist. It is not possible for our brains to perform the many complex tasks they do unless there is an inherited organization to execute, control, and dynamically pattern our myriad ongoing activities. We are never taught how to do these things, nor, probably, could we be. The abilities emerge of their own accord (assuming good health and reasonable physical, psychological, and social circumstances). A parallel was drawn between the mind and what in the computer is called an OS. This parallel is felt to be helpful as a guide in trying to understand how the brain works, even though the mind and brain are much more complex and perform many more functions than any computer and OS that currently exist.

Evidence was presented to demonstrate that the human OS must exist. This evidence came from the fields of neuroanatomy, physical and mental development, cognitive development, and the emergence of abilities and inabilities in autistic-savant children. Further evidence from the psychoanalytic literature showed that there, too, workers had found the existence, emergence, and development of mind were undeniable. Jouvett's (1967a, 1967b, 1972, 1975) work on sleep and dreaming was cited to demonstrate three significant facts: (1) that an OS is not confined solely to man but must exist at least as far down the phylogenetic scale as lower mammals (because they also exhibit SWS and PS), (2) that at least some other animals (e.g., cats) also dream, and (3) that a pacemaker exists (probably in the midbrain) that is directly or indirectly involved with initiating the hallucinations called dreams.

The study and analysis of thousands of dreams has clearly demonstrated the brain's totally untutored, inherited ability on occasion to present its conceptions symbolically. Furthermore, these, usually visual, images frequently provide creative and novel solutions to ongoing problems in the dreamer's life or, failing solution, at least a clear depiction of the dreamer's conception of the problem is made. Each of us knows from personal experience that it is possible to have ideas, to reorder or recombine their elements, and to express them in any or all of several different modes. Each of us also is able to generate and to understand meaningful speech. These are extremely complex tasks, and yet they can be handled well by most children even as young as age 5, before having been exposed to formal schooling. Evidence from children born deaf establishes clearly

that words are not necessary to be able to think. On the other hand, evidence from mentally retarded children shows clearly that some competence with words does not guarantee the ability to think. All this evidence strongly supports the thesis of the existence of an OS and the fact of its inherited nature.

Our software was deemed to be hard-wired in the sense of probably being actual neuronal circuitry and biochemical reactions (particularly but not solely involving the endocrine system). It was agreed that the disappearance of a function because of a lesion in some specific portion of the brain did not imply that that function was localized to that particular region. On the other hand, it was also agreed that there is some structure and specialization in the brain and not all parts are equally able to handle all tasks. Some of the works of Luria and of Nauta (e.g., Luria, 1973; Nauta, 1971) were cited to support the contention that our OS has ramifications everywhere, of course, but is particularly concentrated in the brain stem, hypothalamus, thalamus, limbic system, basal ganglia, and frontal and anterior temporal cortices. Some effects of malfunction in portions of the OS were illustrated by reference to a review article by Livingston (1973) and some empirical work on the psychoses by Flor-Henry (1978). Other work on schizophrenia was then used to show how many of the manifest symptoms are such as would be expected if schizophrenia were regarded as a disease of the OS. Some empirical work of Oscar-Berman (1980) on alcoholics with Korsakoff's syndrome was used to illustrate further how the effects of brain damage in the regions of the OS does produce difficulties in human data processing. Finally, some important work by Yeudall (Note 1, Note 2) was mentioned in which various psychopathologies were consistently implicated with dysfunction of the temporal and frontal brain systems, which, in turn, are part of the postulated human OS.

PROBLEMS FOR THE FUTURE

There is no shortage of unsolved problems connected with the brain and mind. Some of the major outstanding problems are: (1) consciousness, (2) memory, (3) cognitive generation, (4) conative generation, (5) the emergent self and its structure, and (6) life plans or scripts. Consciousness seems to be dependent on conditions in the central gray matter and the frontal and temporal cortices. Penfield (1975) discussed the centrencephalic concept, which he had developed earlier and in which he postulated that mind and consciousness may arise in or near the junction between the thalamus and the midbrain. Penfield also recounted (in an earlier book) how he had observed consciousness (in an epileptic patient on the operating table) first fade and then return to normal as the pressure on a retractor in the

third ventricle was first increased and then decreased. And Bailey and Davis (1942) reported how they had produced cats that hallucinated to varying degrees, depending on the extent of damage to the periaqueductal gray, caused by inserting an instrument through the fourth ventricle. Thus some cats were rendered oblivious to their environments and simply stared into space with widely dilated pupils. Others snarled and spat and hit at imaginary enemies. [It is interesting that this area of the brainstem is close to that in which Jouvett worked (cf. Jouvett, 1975, p. 511).] But these and other empirical facts about changes in states of consciousness do not explain how consciousness is possible, and neither do the monistic and dualistic theories that have heretofore been put forward, at least since the time of Descartes (Savage, 1976). However, since about 1940, when servomechanisms and then computers became available, it has become possible to produce goal-seeking devices and learning and problem solving computers (although admittedly still of relatively limited generality and power). And what has proved possible in the field of artificial intelligence (AI) to date shows considerable promise that, ultimately, man will be able to produce robots with at least consciousness, and possibly even self-consciousness. In fact, even now, depending on how terms are defined, it can be argued that some AI programs already exhibit a form of consciousness. (But see the section on AI in the appendix.)

The problem of cognitive generation is central to creativity. How ideas are processed is one thing, but how they are generated is even more puzzling. Since in most persons the left hemisphere is the verbalizer and the right hemisphere is the visualizer (i.e., literally the image-inaction?), it is conceivable that an idea could, at one and the same time, be contemplated both in words and in images. It must also be true, however, that there is some internal representation of ideas that is neither words nor pictures, just as in the computer there is an internal representation of information that is different from the bit string used to encode that same information for output on, say, the line printer. This internal form must exist, because answers (to puzzles and problems) spring to mind and are only then clothed in words or images for external consumption. It is likely, too, that some form of visual and symbolic imagery is possible at a subcortical level.

Perhaps the most fundamental of all the problems mentioned above is the question of the existence, structure, development, and manner of working of the self. Many investigators (e.g., Allport, 1955; Berne, 1973; Jung, 1971; Kagan, 1976) have been led to different extents toward the conclusion that there is an inherited structure for the self [which encompasses the whole person and hence includes the physique, temperament, intellect (cognitive ability), and character (conative ability)]. It is acknowledged, to a greater or lesser

degree, that this self is emergent and that the individual's ultimate abilities may not necessarily be seen or suspected, even by the person himself, until much later in life. Initially, consciousness in humans seems to be a relatively simple matter of awareness of sensations rather than of self. But soon, cognitive abilities begin to emerge (Kagan, 1976; Piaget & Inhelder, 1969; Spitz, 1959), conative ability (Gesell, 1952; Gesell & Ilg, 1949; Spitz, 1959), speech (Lenneberg, 1967), awareness of self (Gallup, 1979), and, considerably later, moral developments (Kohlberg, 1963, 1964).

Although the idea of one's self may be first realized about age 2, it is usually many years before self-consciousness begins to have considerable impact in one's life. Jung (1971) argues that the true process of developing awareness in depth of the emergent self does not occur until the latter half of life. Berne (1973) argues that each person inherits a mental apparatus that establishes a script (or life plan) based on the beliefs and behaviors prevailing in the parental home. Berne argues also that these scripts are established before age 6 and usually guide the person's behavior for the rest of his life. Berne agrees that it is possible to alter a script later, although this usually requires a lengthy, careful sorting of what the person actually is doing, rather than what he says he is doing.

The ultimate problem in all this, which may never be solved, is to understand the structure of a person's life and how the brain and mind make it possible. It is clear that we are not merely simple stimulus-response beings. We do form intentions and plans, adopt goals, and strive to achieve them. Initially, the child probably is largely determined by his genetics and the parental home, but ultimately, the fully mature adult may select his own goals in keeping with principles of justice and compassion and in conformity with what his brain and mind permit.

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NOTES

1. Since some computer terminology will be used in this work, a cursory overview of computer systems and software has been provided in the appendix.

2. The singular number will be used, although the plural may well be more correct.

3. In these analogies, the limbic system in each hemisphere is considered along with the appropriate projection areas (Livingston, 1973) in the cortex as being an ASP; the association areas of the cortex are considered to be the nonemotional, high-powered CPUs.

APPENDIX

Computer Components

A computer system is composed of at least one of each of the following elements: (1) a central processing unit (CPU) to do the arithmetic and logic, (2) a main storage device, or memory (often called "core"), (3) auxiliary memory devices (e.g., disks, drums, tapes), (4) input/output (I/O) devices, (5) an operator's console to allow the human operator to interact via commands and messages with the CPU.

A large stored program called the operating system (OS) is in charge of the complete system. A portion of OS called the resident supervisor is always in core; other portions are called in as needed from auxiliary memory. Programs executed by the CPU may be divided into two main types: (1) software and (2) user programs. Programs considered to be software are concerned with the operations of the hardware and the necessary housekeeping involved in various tasks, such as fetching and storing data in auxiliary memory, and so on. User programs, as the name suggests, are written by the user to suit his own applications (e.g., a payroll).

In a multiprogramming computer, core is partitioned into several regions, each of which may have one or more programs stored in it. The resident supervisor delegates control to these programs in sequence, depending on some set of priorities. Only one program is actually on stage (i.e., running) at any moment. In a multiprocessor computer system, on the other hand, there are two or more CPUs, each of which can be processing its own program; hence these programs (in the several CPUs) may in fact be processed simultaneously.

Since minicomputers have become so readily available, two modes of organizing multiprocessor systems have become popular. These are called networking and distributed processing (Edwards & Broadwell, 1979, pp. 162-169). The fundamental distinction between them is that networking usually involves a hierarchy of one or more CPUs and a number of minicomputers. Smaller jobs tend to be done locally on the minicomputer, whereas summary results and larger jobs are handled by the main frames. Distributed processing, on the other hand, allows any user at any terminal in the system access to and processing by any other computer in the system. This may be termed a heterarchy. The distinctions between these terms tend not to be drawn too rigidly, particularly as one moves into the field of process control, in which a number of microprocessors, miniprocessors, and main frame(s) may be hooked together to control a process, an industrial plant, or even a company (cf. Kahne, Lefkowitz, & Rose, 1979).

Interruptions

There is a hierarchy of mutually exclusive states in which a CPU may be at any one time (Katzan, 1973, pp. 47-48). It may be either operating or not operating. If operating, it may be either running or waiting. If running, it may be in a problem or supervisory state, and if in the supervisory state, it may be masked or interruptible. Supervisor programs usually have the highest priority, have access to all components, and can preempt components when in contention with user programs. Should one

supervisor program be in contention with another, then one that has control will not relinquish control if it is "masked," but it may if it is "interruptible." In the course of normal operations, a series of interruptions will be generated that disrupt the normal flow of programs through the system. These "interrupts" will be classified by another program in the resident supervisor, called the "interrupt stacker" and placed in appropriate queues awaiting further processing.

A CPU normally executes instructions in sequence, but from time to time an interruption will occur that requires a changed sequence. There are many types of interruptions, but a basic set probably must have at least the following: (1) The OS is alerted by an equipment malfunction, called a "machine check interruption." (2) An erroneous or unusual situation arises while a program is being processed, called a "program interruption." (3) A device other than the CPU needs attention (usually an I/O interruption). (4) A program in execution requires the services of one of the many service programs that are a part of OS (termed a "supervisor call interruption," an SVC). (5) An "external interruption" may come from a timing device; in a multiprocessor system, this might be from inter-CPU signals.

As suggested by Katzan (1973, p. 51), the idea of interruptions is particularly important because it allows the OS to monitor the execution of computer programs. This may form the ultimate basis of introspective thought in human beings.

Artificial Intelligence

Many computer programs have been written in the past 25 years upon which, without further human intervention, decisions have been made by the computer that are generally conceded to be categorizable as intelligent, (cf. Boden, 1977; Oatley, 1978; Winston, 1977). For instance, some computer programs can play very respectable chess, and others can analyze visual scenes and take appropriate action.

Hence, the question arises of whether there may be "consciousness" in a multiprogramming multiprocessor. Since the OS may be "aware" of changes that have taken place in the performance of user programs, would it be possible, ever, for such a computer to be "aware" of itself? It seems to me possible that the OS could alter a data set that it maintains about itself, in which could be recorded data about its performance of particular tasks as measured by some formula or set of rules. Thus, in this sense, the computer could be "aware" of itself and its "good" or "bad" performance vis-à-vis those rules, but I do not know that we will ever be able to make a computer "feel good" about, say, having won a difficult game of chess. Nor do I think we will ever be able to make a computer "enjoy" a sunset, a Beethoven quartet, or a gourmet meal.

The assumption that "mind" exists and amounts to a timing and organizing mechanism that supervises the operation of other neural circuits does not imply an infinite regress of circuits watching circuits that watch circuits, and so on. Nor does it imply the existence of a "soul" that is capable of operation independently of any material body. The OS in a computer is a program that facilitates and supervises the performance of other programs, but the hierarchy of programs is finite; furthermore, the OS can only operate in the hardware. It cannot execute "out-of-computer" calculations.