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Let us ourselves look at the matter in the largest possible way. Modern psychology, finding definite psycho-physical connections to hold good, assumes as a convenient hypothesis that the dependence of mental states upon bodily conditions must be thoroughgoing and complete . . . According to the general postulate of psychology just referred to, there is not a single one of our states of mind, high or low, healthy or morbid, that has not some organic process as its condition. Scientific theories are organically conditioned just as much as religious emotions are; . . . so of all our raptures and our drynesses, our longings and pantings, our questions and beliefs. They are equally organically founded, be they religious or of non-religious content.

[However,] to plead the organic causation of a religious state of mind, then, in refutation of its claim to possess superior spiritual value, is quite illogical and arbitrary . . . None of our thoughts and feelings, not even our scientific doctrines, not even our dis-beliefs, could retain any value as revelations of the truth, for every one of them without exception flows from the state of its possessor's body at the time.

William James, *The Varieties of Religious Experience*, 1902/1929

INTRODUCTION: FORMS OF CONSCIOUS EXPERIENCE

Over the past two centuries, since the pioneering observations of Frances Gall and G. Spurtzheim (1809/1969), it has become clear that there is a special relation between brain tissue and the varieties of conscious experience. Gall initiated the procedure of comparing the locus of brain pathology with aberrations of behaviors of the patients whose brains he examined—a procedure that is continued today in the active field of clinical neuropsychology.

Though, on the whole, we today accept this special relation between brain and conscious experience, we are not at all agreed on the basic nature of the relationship nor on the consequences our understanding of this nature might have on our understanding of ourselves and our relation to others. In this respect we have apparently come no further than philosophers of the past two millennia. I believe the time is ripe for an advance in understanding because of the amount of detailed experimental and observational data now available which, when properly interpreted, can provide

specific transfer functions that bind the mind-matter relation into a coherent science.

To begin with, the advent of computer science has provided the transparency that was lacking in an earlier period. I use my computer as a word processor by typing English words and sentences. The word processing system, by virtue of an operating system, assembler, ASCII, octal or hexadecimal, converts the keyboard input to binary which is the "language" of the computer. There is nothing in the description of English and that of binary machine language that appears to be similar. Despite this, by virtue of the various transformations produced in the encoding and decoding operations of the various stages leading from typescript to binary, the information of the typescript is preserved in the binary language of the operation of the computing machine.

In a similar fashion, there is little in conscious experience that resembles the operations of the neural apparatus with which it has such a special relation. However, when the various transformations, the transfer functions, the codes that intervene between experience and neural operations are sufficiently detailed, a level of description can be reached in which the transformations of experience are homomorphic with the "language" used by the brain. As will be reviewed in this essay, this language is the language of the operations of a microprocess taking place in synaptodendritic fields, a mathematical language similar to that which describes processes in micro (that is, subatomic) physics. Thus, the relation between brain and conscious experience becomes implemented at the microprocessing level. At neuronal and neural system levels the microprocesses become variously configured to produce the variety of conscious experiences.

First, there are *electrochemical synaptodendritic states* which are coordinate with *states of consciousness*. The operation of anesthetics and the very active field of psychoneuropharmacology attest to this relationship. Anesthetics work on a level that produces a quantitative rather than a qualitative change in consciousness; whereas catechol and indole amines act at specified brain sites to produce a variety of states of consciousness such as wakefulness and sleep; depression and elation; and probably even dissociated states such as those seen in schizophrenia. Relative concentrations of blood glucose and osmolarity produce hunger and thirst; sex hormones produce sexual feelings; and peptides such as the endorphins and enkephalins are related to the experiences of pain and stress and their converse, well being.

Second, there are detailed descriptions of the relations between the *sensory systems of the brain* and the sensory aspects of perception: these are responsible for the organization of the *contents* of consciousness (see for example, Pribram 1991, for a detailed account of the neural systems and neuronal functions involved in figural vision).

Third, states of consciousness often determine contents and, as often are determined by them. When hungry one tends to see restaurant signs (Zeigarnik 1972); walking past the fresh aromas emanating from a bakery whets the appetite. This connection between states and the contents of consciousness is mediated by a process—a process ordinarily called *attention*.

STATES OF CONSCIOUSNESS: THE SYNAPTODENDRITIC MICROPROCESS

The Mutual Exclusiveness of Conscious States

We ordinarily distinguish different states of consciousness much as does the physician and surgeon: when someone responds to prodding (for example, by grumbling "Oh leave me alone! Can't you see I'm trying to get some sleep!") we attribute to him a conscious state. When, on the other hand his response is an incoherent thrashing about, we say he is stuporous and if there is no response at all, we declare him comatose.

The interesting thing about such states is their mutual exclusiveness regarding experience: what is experienced in one state is not readily available to experience in another. Such state exclusiveness emerges in all sorts of observations: state-dependent learning in animal and human experiments; the fact that salmon spawning pay no attention to food, while when they are in their feeding state sexual stimuli are ignored; the observation in hypnosis that a person can be made unaware posthypnotically of suggestions made during hypnosis (although he carries out these suggestions); and the dissociation between experiences (and behavior) taking place during "automatisms" in temporal lobe epileptics and their ordinary state.

The evidence obtained in all of these situations suggests that the same basic synaptodendritic electrochemical substrate becomes variously organized to produce one or another conscious state. Hilgard (1977) has conceptualized these various organizations as a more or less "vertical" rearrangement of the substrate. One might picture such arrangements to resemble those that take place in a kaleidoscope: a slight rotation and an entirely new configuration presents itself (Pribram and Gill 1976, Chapter 5). Slight changes in relative concentrations of chemicals in the organization of synaptodendritic microprocesses in specific locations could, in similar fashion, result in totally different conscious states.

The Cortical Microprocess

To demonstrate the basis upon which the organization of synaptodendritic processing domains operate and to portray it in a novel and realistic fashion we performed the following experiments on the rat somatosensory system. This system is convenient and the relation between whisker stimulation and central neural pathways has been extensively studied (see review by Gustafson and Felbain-Kermadiaz, 1977). Whiskers were stimulated by a set of rotating cylinders, each grooved with equally spaced steps, the step width and adjacent grooves subtending equal angles. Three cylinders were used with their steps measuring 30 degrees, 15 degrees, and 7.5 degrees, respectively. The cylinders were rotated at eight different speeds, varying from 22.5 degrees/second to 360 degrees/second. (The rotating

cylinders were meant to mimic the drifting of gratings across the retinal receptors in vision.)

In most of our experiments an entire array of whiskers was subjected to contact with the rotating cylinders. This was done in order to bring the results of these somatosensory experiments into register with those performed in the visual system where an entire array of receptors is stimulated by the drifting grating.

Axonal spike trains recorded from single electrodes can be attributed to three separable processes: (1) those due to the sensory input per se, (2) those that are intrinsic to the operations of the synaptodendritic field potentials, and (3) those that reflect the output of the axon hillock (Pribram *et al.* 1981, Berger and Pribram 1992). In our experiments, sensory influences are generated by the frequency (spectrum) of the stimulus as modulated by the spacings of the grooves on the cylinders and the speed with which the cylinders are rotated. The results thus provide maps of the number of bursts or spikes generated at each spectral location as determined by the spatial and temporal parameters of the sensory input. (Figures 10.1a-d and 10.2a-f). The activity above or below baseline that resulted from whisker stimulation is plotted as a manifold describing total number of bursts (or spikes) per 100 seconds of stimulation. Spatial frequencies are scaled in

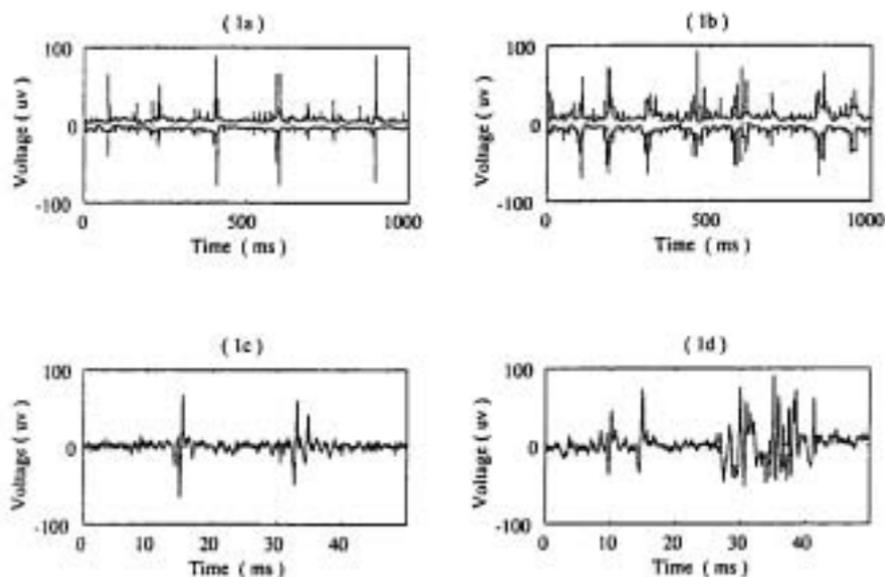


Figure 10.1 (1a) One second of a typical recording with no whisker stimulation (baseline). (1b) Data from the same location during one second of whisker stimulation (spatial frequency=24 grooves/revolution; temporal frequency=0.125 rps). Figures (1c) and (1d) show individual units during 50 msecs of baseline (1c) and the superposition of units during whisker stimulation.

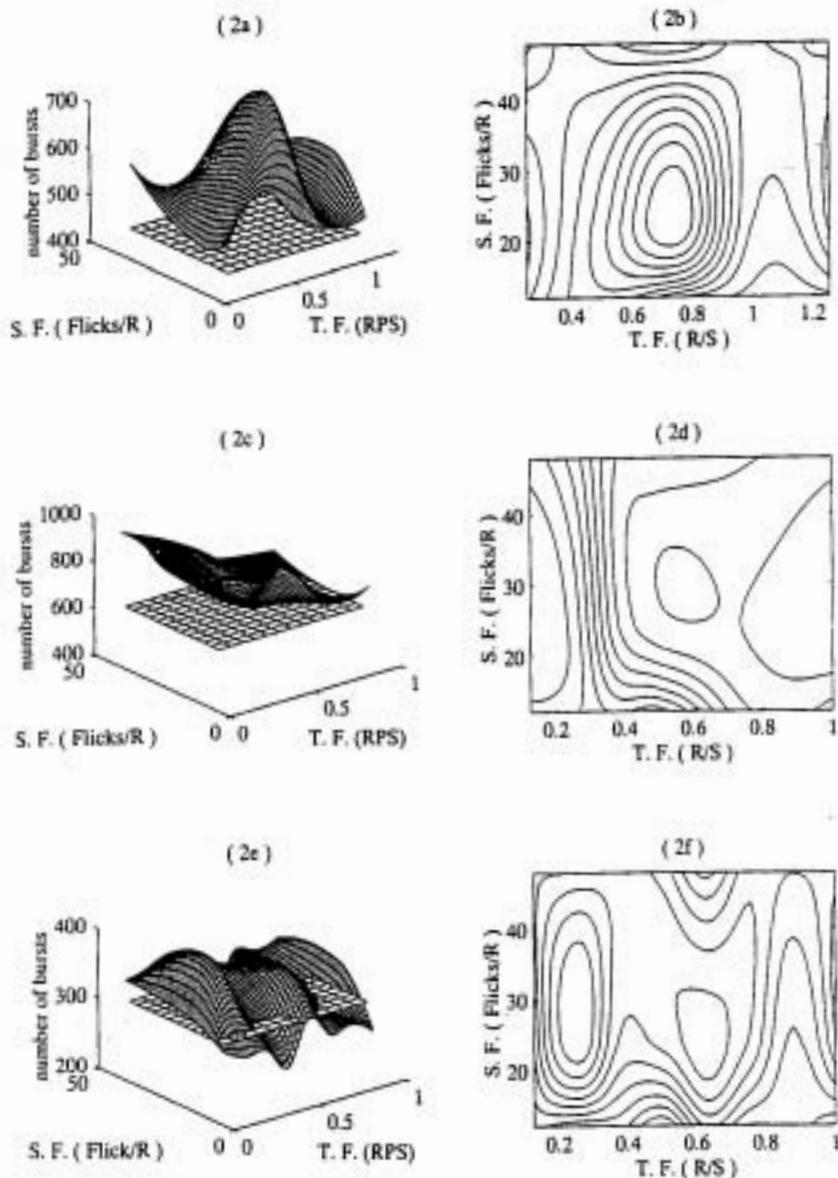


Figure 10.2 Examples of receptive field manifolds and their associated contour maps derived by an interpolation (spline) procedure from recorded whisker stimulation. The contour map was abstracted from the manifold by plotting contours in terms of equal numbers of bursts per recording interval (100 seconds). Each figure shows baseline activity (no whisker stimulation) at a given electrode location as a gr-plane located in terms of number of bursts per 100 seconds.

terms of grooves per revolution, while temporal frequencies are scaled in terms of revolutions per second. Thus, the density of stimulation of a whisker (or set of whiskers) is a function of both the spacings of the cylinder grooves and the speed with which the cylinder rotates. It is this density per se that composes the spectral domain.

In 27 experiments single whiskers were isolated and stimulated. Whiskers were identified according to accepted nomenclature as described by Simons (1978). The receptive field potential manifolds derived from such stimulations were irregular and broadly tuned to both spatial or temporal frequency. The intrinsic operations governing the configuration of the synaptodendritic field potentials are constrained by parameters such as the anatomical extent of each receptive field and the functional inhibitory and excitatory relationships among such fields. Our analyses were derived from both bursts of unit activity and from single units. We therefore sought to determine the relationships between the manifolds derived from bursts and those derived from single units composing the bursts.

A manifold (Figure 10.3) constructed from bursts is shown to encompass those of the individual units composing the bursts: Figures 10.4a-d illustrate manifolds from the four single units which compose the bursts. These units were identified using a template constructed from a spike sorting procedure that discriminated the shape of the action potential (spike) on the basis of spike amplitude and recovery slope. The four single unit manifolds show a gradual change in shape corresponding to slight changes in location within the burst manifold: Figures 10.4a and 10.4b illustrate two peaks which progressively become combined into a single broad peak in the manifolds of Figures 10.4c and 10.4d. This demonstration of continuity between two levels of analysis (bursts and single units) strongly supports the view proposed by Pribram (1991) that extended networks of synaptodendritic

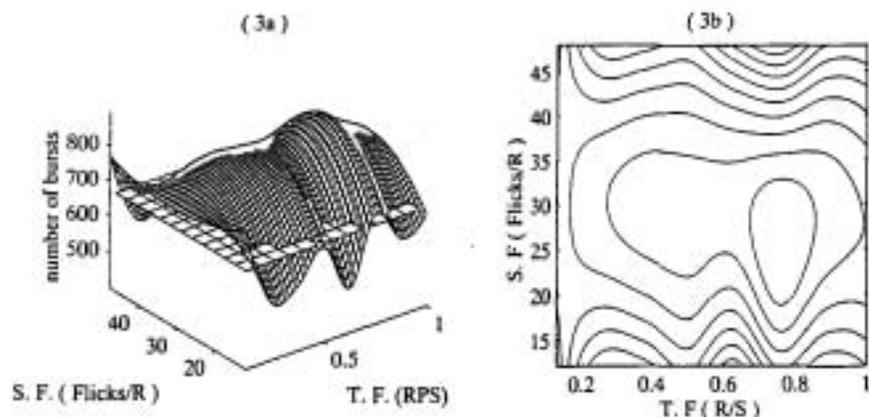


Figure 10.3 Lateral (3a) view of an empirically derived burst manifold and its associated contour map (3b).

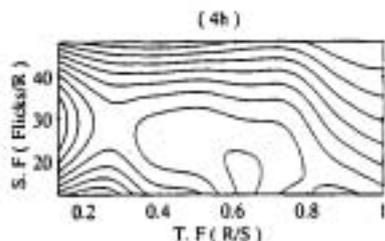
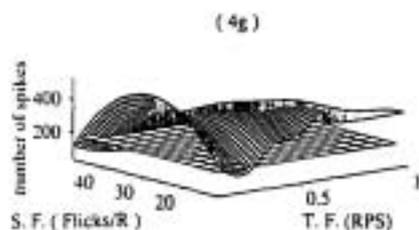
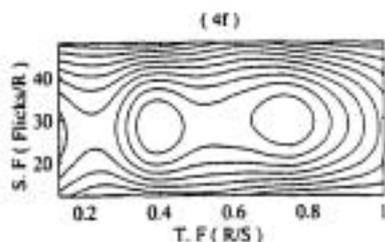
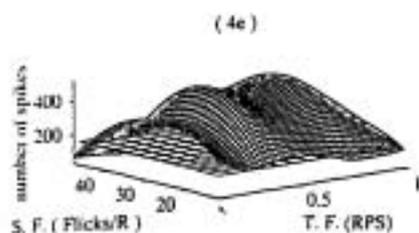
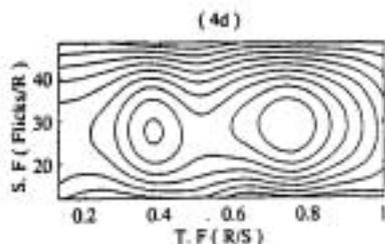
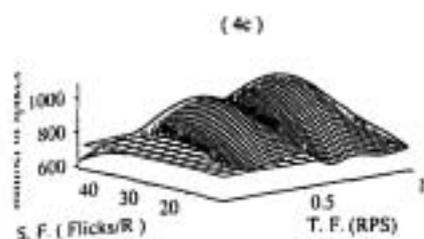


Figure 10.4 These figures illustrate manifolds and their associated contour maps from four single units which compose the bursts used to construct the manifold in Figure 10.3.

fields serve as the processing medium, and therefore, single neurons are sampling from overlapping areas of the synaptodendritic network.

The similarity of these manifolds obtained from recordings made from the somatosensory cortex to the receptive field characteristics demonstrated in the primary visual cortex (DeValois and DeValois 1988, Pollen and Taylor 1974, Pribram and Carlton 1986, Daugman 1990) suggests that this processing medium is ubiquitous in the cortical synaptodendritic network.

The manifolds derived from our data are constructed of two orthogonal dimensions: one dimension reflects the spatial frequency of the stimulus and the other its temporal frequency. Because spatial and temporal variables constrain the spectral density response, a Gabor-like rather than a

simple Fourier representation describes our results. Thus the results of our experiments can be interpreted in terms of an information field composed of Gabor-like elementary functions, that is, of truncated two dimensional sinusoids.

THE CONTENTS OF CONSCIOUSNESS

Objective Consciousness: The Posterior Cerebral Convexity

The Projection of Sensory Experience—The Perifissural Cortex Surrounding the major fissures of the primate brain lie the terminations of the sensory and motor projection systems. Rose and Woolsey (1949) and Pribram (1960) have labeled these systems extrinsic because of their close ties (by way of a few synapses) with peripheral structures. The sensory surface and muscle arrangements are mapped more or less isomorphically onto the perifissural cortical surface by way of discrete, practically parallel lines of connecting fibre tracts. When a local injury occurs within these systems a sensory scotoma, or a scotoma of action, ensues. A scotoma is a spatially circumscribed hole in the "field" of interaction of organism and environment: a blind spot, a hearing defect limited to a frequency range, a location of the skin where tactile stimuli fail to be responded to. These are the systems where what Henry Head (1920) called epicritic processing takes place. These extrinsic sensory-motor projection systems are so organized that movement allows the organism to project the results of processing away from the sensory (and muscular) surfaces where the interactions take place, out into the world external to the organism. Thus processing within these extrinsic systems constructs an objective reality for the organism.

In between the perifissural extrinsic regions of cortex lie other regions of cortex variously named association cortex (Fleschig 1900), uncommitted cortex (Penfield 1969), or intrinsic cortex (Pribram 1960). These names reflect the fact that there is no apparent direct connection between peripheral structures and these regions of cortex that make up most of the convexity of the cerebrum.

The Personal/Extrapersonal Distinction—The Basal Ganglia and the Right Hemisphere Lesions of the intrinsic cortex of the posterior cerebral convexity result in sensory-specific agnosias in both monkey and man. Research on monkeys has shown that these agnosias are not due to failure to distinguish cues from one another, but due to making use of those distinctions in making choices among alternatives (Pribram and Mishkin 1955, Pribram 1969). This ability is the essence of information processing in the sense of uncertainty reduction (Shannon and Weaver 1949), and the posterior intrinsic cortex determines the range of alternatives, the sample size which a particular informative element must address. A patient with

agnosia can tell the difference between two objects but does not know what the difference means. As Peirce (1934) once noted, what we mean by something and what we mean to do with it are synonymous. In short, alternatives, sample size, choice, cognition, information in the Shannon sense, and meaning are closely interwoven concepts. Finally, when agnosia is severe it is often accompanied by what is termed "neglect." The patient appears *not* only not to know that he doesn't know but to actively deny the agnosia. Typical is a patient I once had who repeatedly had difficulty in sitting up in bed. I pointed out to her that her arm had become entangled in the bedclothes—she would acknowledge this momentarily, only to "lose" that arm once more in a tangled environment. Part of the perception of her body, her personal consciousness seems to have become extinguished.

These results can readily be conceptualized in terms of extrapersonal and personal objective consciousness. For a time it was thought that personal body space depended on the integrity of the frontal intrinsic cortex and that the posterior convexal cortex was critical to the construction of extrapersonal reality (see for example, Pohl 1973). This scheme was brought to test in my laboratory in experiments with monkeys (Brody and Pribram 1978) and patients (Hersh 1980, Ruff, Hersh, and Pribram 1981) and found wanting. In fact, the personal/extrapersonal distinction involves the parietal cortex; in humans, most often the right parietal cortex and related structures. Studies by Mountcastle and his group (Mountcastle *et al.* 1975) in monkeys demonstrate how cells in the convexal intrinsic cortex respond when an object is within view, but only when it is also within reach. In short, our studies on patients and those of others have been unable to clearly separate the brain locations that produce agnosia from those that produce neglect. Furthermore, the studies on monkeys as well as those on humans (McCarthy and Warrington 1990, Chapter 2) indicate that agnosia is related to meaning as defined by corporeal use.

In monkeys the disturbances produced by restricted lesions of the convexal intrinsic cortex are also produced by lesions of the parts of the basal ganglia to which those parts of the cortex project. This finding takes on special meaning from the fact that lesions of the thalamus (which controls the relaying of sensory input to cortex) fail to produce such effects. Further, recent experiments have shown that the neglect syndrome can be produced in monkeys by lesions of the dopaminergic nigrostriatal system (Wright 1980). This special connection between intrinsic (recall that this is also called association) cortex and the basal ganglia further supports the conception that these systems make possible, on the basis of use, the distinction between an objective personal self (the "me") and, an extrapersonal reality. (See Pribram 1991, Lecture 6 for a detailed exposition of how this process operates.) An excellent review of the history of differentiating this objective "me" from a historical "I" can be found in Hermans, Kempen, and van Loon (1992). The next sections develop the relation between brain processing and the "I."

Episodic Consciousness: The Limbic Forebrain

Instinct as a Species-Shared Propensity When resections were restricted to the amygdala and adjacent pole of the temporal lobe, the marked taming of the monkeys that had followed resection of the entire temporal lobe (Sanger-Brown and Schaefer 1888, Klüver and Bucy 1937) are reproduced (Pribram and Bagshaw 1953). Just what might this behavioral change signify?

First it was determined that not only were the monkeys tamed, but they also put everything in their mouths, gained weight, and increased their sexual behavior—all effects that had also followed the total temporal lobectomy. These changes in behavior were summarized under the rubric of the “four Fs”: fighting, fleeing, feeding, and sex (Pribram 1960).

Historically these apparently disparate behaviors were classified together as “instinct” (a term still used to describe the processes underlying such behaviors in the psychoanalytic literature). More recently this concept came into disfavor (see for example, Beach 1955) and ethologists substituted the category “species specific” behaviors for instinct because these behaviors can be shown to have a common genetic component. But this substitution loses much of the meaning of the older terminology: Human language is species-specific but not instinctive in the earlier sense. My preference is to retain the concept of instinct as descriptive of the four F's: What these behaviors have in common is the fact that their patterns are shared by practically all species. What makes the study of geese and other birds so interesting is that we recognize our own behavior patterns in the descriptions provided by ethologists (see for example, Lorenz 1969). It is therefore *species-shared* behavior-patterns that are of interest in tracking the effects of amygdalectomy.

The Boundaries of an Episode The apparently disparate behaviors that characterize the four Fs were shown by careful analysis to be influenced by a common process. It is worth summarizing the highlights of this analysis because identifying a common process operating on apparently disparate behaviors is a recurring problem in behavioral neuroscience. In behavioral genetics the same problem entails identifying genotypes from phenotypical behaviors. Thus, qualitative and quantitative determinations were made in each of the four Fs with the following results.

In a social hierarchy fighting and fleeing were both diminished provided there was a sufficiently skillful antagonist (Rosvold, Mirsky, and Pribram 1954). In the study reported by Sanger-Brown and Schaefer (1888), when a monkey was returned to the social colony after amygdalectomy, he “voluntarily approaches all persons—and fellow monkeys indifferently.” Also, having just interacted with his fellow monkey, and perhaps having been trounced, “he will go through the same process, as if he had entirely forgotten his previous experience.”

This change in processing what would ordinarily be a deterrent outcome of behavior was dramatically demonstrated by displaying a lighted match to such monkeys. They would invariably grab the match, put it into their mouth, dousing the flame, only to repeat the grab when the next lit match was presented. This behavior could be elicited for a hundred consecutive trials unless either the monkey or the experimenter became bored before the session was ended (Fulton *et al.* 1949).

The increases in feeding that follow amygdectomy were also shown to be due to a failure placing limits on actions. For instance, as reported by Sanger-Brown and Schaefer, monkeys with such resections appear to be indiscriminate in what they pick up, put in their mouths, and swallow. But when tests were performed and a record was kept of the order in which the food and nonfood objects were chosen, it turned out that the order of preference was undisturbed by the brain operation; only now the monkeys would continue to pick up additional objects beyond those that they had chosen first (Wilson 1959). In fact amygdectomized animals may be a bit slow to start eating but continue eating far past the point when their controls stop eating (Fuller, Rosvold, and Pribram 1957).

These disturbances in feeding after amygdectomy were shown to be due to connections with the satiety mechanism centered in the ventromedial region of the hypothalamus. For instance, a precise relationship was established between the amount of carbachol injected into the amygdala and amount of feeding (or drinking) once these behaviors had been initiated (Russel *et al.* 1968). Injections into the ventromedial hypothalamic region simply terminate feeding.

Modulation of a stop process was also shown responsible for changes in fighting behavior. Fall in a dominance hierarchy after amygdectomy, when it occurred, was related to the amount of aggressive interaction between the dominant and submissive animals of the group. After amygdectomy such interactions were overly prolonged leading to a reorganization of the dominance hierarchy. It was as if the amygdectomized monkeys approached each interaction as novel. Prior experiences, which modulated the behavior of the control subjects, seemed to have little influence after amygdectomy. This finding characterizes many of the experimental results to be described shortly.

Analyses of the effects of amygdectomy and electrical stimulations of the amygdala on avoidance (fleeing) behavior brought a similar conclusion. Escape behavior is unaffected and sensitivity to shock is not diminished (Bagshaw and Pribram 1968). Nor is there a change in the generalization gradient to aversive stimulation (Hearst and Pribram 1964a, 1964b). What appears to be affected primarily is the memory aspect of avoidance—the expectation based on familiarity with the situation that aversive stimulation will occur. Such expectations are ordinarily referred to as feelings of fears that constrain behavior.

The theme recurs when the effects of amygdectomy on sexual behavior are analyzed. The hypersexuality produced by the resections is found to be due to an increased territory and range of situations over which the behavior is manifest: Ordinarily cats perceive unfamiliar territory as inappropriate for such behavior (see Pribram 1960, for review). Sexual behavior is limited to familiar situations and situations become familiar as a consequence of rewarding sexual encounters.

The importance of the amygdala in more generally determining the spatial and temporal boundaries of a series of experiences or a behavioral routine—in short, an episode—is attested by the results of another set of experiments. Kesner and DiMattia (1967) presented a series of cues to animals to allow them to become familiar and then paired the initial, intermediate, and final cues of the series with novel cues in a discrimination. When similar tasks are administered to humans, they recall the initial and final cues of the series more readily than they recall the intermediate ones. These are termed the primacy and recency effects. Unoperated monkeys showed both effects in Kesner's experiments. However, after amygdectomy, monkeys failed to show either a recency or a primacy effect. If the series is taken to be an episode, the effects of amygdectomy can be considered to impair the demarcation of an episode. As described shortly, after resections of the far frontal cortex, ordering within an episode becomes deficient.

Familiarization: Episode as Context The demonstration of an episode is effected by an orienting reaction. What is oriented to, the novel, depends on the familiar, which serves as the context within which an event becomes appreciated as novel.

Familiarization is fragile. The process is readily disrupted by head injury or distraction. Some of the factors governing distractibility such as pro- and retroactive interference are well known. Amygdectomy and resections of forebrain systems related to the amygdala have been shown to increase susceptibility to distraction (Douglas and Pribram 1969, Grueninger and Pribram 1969). Resistance to distraction is furnished by a viscerotonic "booster" that places a value on the experience and thus leads to a *feeling* of familiarity. It is this booster process in which the amygdala is involved (Pribram, Douglas, and Pribram 1969).

Familiarity is a conscious feeling regarding an experience. In the clinic, patients who have a lesion in the region of the amygdala (and the adjacent horn of the hippocampus) describe experiences that are called "jamais vu" and "déjà vu"—the patient will enter a place such as his living room and experience a "jamais vu," a feeling of "never having seen," of complete unfamiliarity. Others will come into a place they have never been and feel that they have "already seen," are already, "déjà," completely familiar with it.

In the laboratory, familiarity has been shown to be related to reinforcement history. Monkeys were trained to select one of two cues on the basis of a 70 percent reinforcement schedule: that is, selection of one cue was rewarded on 70 percent of the trials; selection of the other cue was rewarded

on 30 percent of the trials. Then the cue that had been most rewarded was paired with a novel cue. Control monkeys selected the previously rewarded cue. Monkeys who had their amygdalas removed selected the novel cue. Familiarization by virtue of previous reinforcing experience had little effect on monkeys who lacked the amygdala (Douglas and Pribram 1966). These monkeys were performing in a "jamais vu mode."

The process by which the history of reinforced episodes leads to conscious emotional and motivational states can be described as follows:

Consequences are the outcomes of behavior. In the tradition of the experimental analysis of behavior, consequences are reinforcers or deterrents that influence the recurrence of the behavior of which they are the consequences. Consequences are thus a series of events (Latin *ex-venire*, out-come), outcomes that guide action and thereby attain predictive value (confidence estimates). Such consequences, that is, sequence of events that form their own confidential context become, in humans, envisioned eventualities (Pribram 1963, 1971, 1991, Lecture 10 and Appendix G).

Confidence implies familiarity. Experiments with monkeys (Pribram *et al.* 1979) and humans (Luria, Pribram, and Homskaya 1964) have shown that repeated exposure to a stimulus habituates, that is, the orienting reaction gives way to familiarization. Familiarization is disrupted by limbic (amygdala) and frontal lesions (Pribram *et al.* 1979, Luria, Pribram, and Homskaya 1964). Disruption leads to repeated distraction and thus the outcomes-of-behaviors, events, become inconsequential. When intact, familiarization is segmented by orienting reactions into episodes within which confidence values can become established.

In such an episodic process the development of confidence is a function of coherences and correlations among the events being processed. When coherence and correlation spans multiple episodes, the organism becomes *committed* to a course of action (a prior intention, a strategy) which then guides further action and is resistant to perturbation by particular orienting reactions (arousals). The organism is now *competent* to carry out the action (intention-in-action; tactic). Particular outcomes now guide competent performance, they no longer produce orienting reactions (Brooks 1986, Pribram 1980). This cascade which characterizes episodic processing leads ultimately to considerable autonomy (an emotional or motivational state) of the *committed* competence. This state is not some vague feeling, however: Contents specific to the reinforcement history are addressed.

NARRATIVE CONSCIOUSNESS: THE FAR FRONTAL CORTEX AND THE LEFT HEMISPHERE

As is well known, frontal lesions were produced for a period of time in order to relieve intractable suffering, compulsions, obsessions, and endogenous depressions. When effective in pain and depression, these psychosurgical procedures portrayed in man the now well-established functional

relationship between frontal intrinsic cortex and the limbic forebrain which was undertaken in nonhuman primates as a result of this clinical experience (Pribram 1950, 1954, 1958a, 1958b). Further, frontal lesions can lead either to perseverative, compulsive behavior or to distractibility in monkeys, and this is also true of humans (Pribram *et al.* 1964, Oscar-Berman 1975). Extreme forms of distractibility and obsession are due to a lack of "sensitivity" to feedback from consequences. Both the results of experiments with monkeys (Pribram 1960, 1962) and clinical observations attest to the fact that subjects with frontal lesions, whether surgical, traumatic, or neoplastic, fail to be guided by consequences (Luria, Pribram, and Homskaya 1964, Konow and Pribram 1970).

In a continually changing situation where episodic demarcation of consequences becomes difficult, or when transfer among the eventualities that comprise contexts is blocked, other resources must be mobilized. Such situations demand executive intervention if action is to be consequential. This part of the essay addresses the issue of an executive processor, a brain system that directs and allocates the resources of the rest of the brain. Ordinarily, input from sensory or internal receptors preempts allocation (for discussion see Miller, Galanter, and Pribram 1960) by creating a "temporary dominant focus" of activation within one or another brain system (for review, see Pribram 1971a, pp. 78-80). However when extra demands are placed on the routine operations of allocation, coherences among proprieties and priorities must be organized, and practical inference initiated. Proprieties must structure competencies, priorities must be ordered and practicalities assessed.

Proprieties, Priorities, and Practicalities The far frontal cortex is surrounded by systems that, when electrically excited, produce movement and visceromotoric effects. On the lateral surface of the frontal lobe lies the classical precentral motor cortex (for review see Bucy 1944, Pribram 1991, Lecture 6). On the mediobasal surface of the lobe lie the more recently discovered "limbic" motor areas of the orbital, medial frontal, and cingulate cortex (Kaada, Pribram, and Epstein 1949, Pribram 1961). It is therefore likely that the functions of the far frontal cortex are, in some basic sense, related to these somatomotor and visceromotoric effects.

At the same time, the far frontal cortex derives an input from the medial portion of the thalamus, the *n. medialis dorsalis*. This part of the diencephalon shares with those from anterior and midline nuclei (the origins of the input to the limbic cortex) an organization different from that of the projections from the ventrolateral group of nuclei to the cortex of the convexity of the hemisphere (see Chow and Pribram 1956, Pribram 1991 for review).

The close anatomical relationship of the far frontal cortex to the limbic medial forebrain is also shown by comparative anatomical data. In cats and other nonprimates, the gyrus proreus is the homologue of the far frontal cortex of primates. This gyrus receives its projection from the midline magnocellular portion of the *n. medialis dorsalis*. This projection covers a good

share of the anterior portion of the medial frontal cortex; gyrus preceus on the lateral surface is limited to a narrow sliver. There appears to have been a rotation of the medial frontal cortex laterally (just as there appears to have occurred a rotation medially of the occipital cortex—especially between monkey and man) during the evolution of primates.

From these physiological and anatomical considerations it appears likely that the far frontal cortex is concerned with relating the motor functions of the limbic to those of the dorsolateral convexity. This relationship has been expressed by Deecke *et al.* (1985) in terms of the what, when, and how of action.

Deecke *et al.* (1985) concluded in an extensive review of their studies using electrical recordings made in humans that: The orbital cortex becomes involved when the question is what to do; the lateral cortex becomes active when the question is how something is to be done, and the dorsal portions of the lobe mediate when to do it. According to the anatomical connections of the far-frontal portions of lobe, described below, "what" can be translated into propriety, "how" into practicality, and "when" into priority.

On an anatomical basis, the far frontal systems have been shown to comprise three major divisions (see Pribram 1987, 1990 for review): One, an orbital, is derived from the same phylogenetic pool as, and is reciprocally connected with, the amygdala (and other parts of the basal ganglia such as the *n. accumbens*, which have been shown to be involved in limbic processing). As might be predicted from the role of the amygdala in familiarizing, in *déjà* and *jamais vu* phenomena, this orbital system augments and enhances sensitivities as to what to do, to propriety based on episodic processing (see below).

The second, a dorsal system, is derived from the same root as, and has connections with, the hippocampal system which includes the limbic medial frontal-cingulate cortex. As might be expected from the involvement of the hippocampus in recombinant processing—in innovation—the dorsal far frontal system controls flexibility when actions are to be engaged, in ordering priorities to ensure effective action.

The third, a laterally located system has strong reciprocal connections with the posterior cerebral convexity. It is this system that involves the far frontal cortex in a variety of sensory-motor modalities when sensory input from the consequences of action incompletely specifies the situation. In such situations practical inference becomes necessary.

Organizing Coherence In addition to its demarcation by successive orienting reactions, a defining attribute of an episode is that what is being processed coheres—processing must deal with covariation in terms of familiarity, equivalence, and novelty. Covariation can lead to interference, thus resulting in the inability to order the processing of events. Recall that primacy and recency effects were impaired after amygdala and hippocampal damage. With far frontal damage, monkeys show impairment in processing the latter part of the middle of a series. This

impairment is attributed to increased pro- and retroactive interference among items in the series (Malmo and Amsel 1948).

The impairment is also shown by patients with damage to their frontal cortex. These patients fail to remember the place in a sequence in which an item occurs: The patients lose the ability to "temporally tag" events, that is, to place them within the episode. With such patients, Milner (1971, see also Petrides and Milner 1982) performed a series of experiments demonstrating how the processing impairment affects the middle portions of an episode. In her studies, it is *relative recency*, the *serial position* of covarying experiences, that becomes muddled. Other patients with fronto-limbic damage are described by Kinsbourne and Wood (1975). In keeping with the proposals put forward in this essay, they interpret the impairment in processing serial position as due to a derangement of the context that structures an episode.

Fuster (1988) conceptualized the far frontal processing of context in terms of cross-temporal contingencies. Relative recency, for instance, implies that a temporal context exists within which recencies can be relative to one another. However, as indicated by experimental results in which spatial context is manipulated, as in variants of object constancy tasks (Anderson *et al.* 1976) the contextual influence can be spatiotemporal as well as temporotemporal. In fact, in other experiments (Brody and Pribram 1978, Pribram, Spinelli, and Kamback 1967) data were obtained indicating far frontal involvement whenever processing is influenced by two or more distinct sets of covarying contextual contingencies, even when both are spatial.

The computation of this covariation demands that cross-temporal, spatiotemporal, and cross-spatial contingencies be processed. In classical and operant conditioning, the consequences of behavior are contiguous in time and place with the stimulus conditions that initiate the behavior. Contiguity determines the episode or conditioning "trial." When contiguity is loosened, stimulation that intervenes between initiation and consequence has the potential to distract and thus to prevent the processing of covariation. Processing is destabilized. Perturbation is controlled only if a stable state, established coherence, instructs and directs the process.

By virtue of the processes mediated by the middle part of the far frontal cortex covarying episodes are woven into a story expressed in language when the left hemisphere becomes engaged. This story can become a narrative, the myth by which "I" live. This narrative composes and is composed of an intention, a strategy that works for the individual in practice, a practical guide to action in achieving (temporary) stability in the face of a staggering range of variations of events (Pribram 1991, 1992). When the narrative becomes dysfunctional, as during endogenous depression or the persistence of obsessions or compulsions, alleviation of symptoms can be produced by changing the neural substrate of such persistence, that is changing the neural substrate of the "I."

Consciousness is manifest (by verbal report) when familiarization is perturbed, an episode is updated and incorporated into the narrative (Pribram 1991, Appendices C and D). Consciousness becomes attenuated when actions and their guides cohere—the actions become skilled, graceful and automatic (Miller, Galanter, and Pribram 1960).

TRANSCENDENTAL CONSCIOUSNESS: THE FAR FRONTAL CORTEX AND THE RIGHT HEMISPHERE

As noted in the epigram that introduces this essay, James did not limit his exploration to ordinary states of consciousness. The esoteric tradition in Western culture and the mystical traditions of the Far East are replete with instances of uncommon states that produce uncommon contents. These states are achieved by a variety of techniques such as meditation, Yoga, or Zen. The contents resulting from processing in such states appear to differ from ordinary feelings or perceptions. Among others, experiences such as the following are described (Morse, Venecia and Milstein 1989 and Stevenson 1974, for review): (1) oceanic, that is, a merging of corporeal and extracorporeal reality, and out-of-body, that is, corporeal and extracorporeal realities continue to be clearly distinguished but are experienced by still another reality: "a meta-me," or (2) the "I" becomes a transparent throughput experiencing everything everywhere, there is no longer a segmentation of experience into episodes; nor do events become enmeshed in a narrative structure. All of these experiences can be induced by drugs including anesthetics that are known to act on the neural cytoskeleton and the synaptodendritic microprocess. As to contents, they are often attributed to some encompassing structure. It is these transcendental contents which address domains that are ordinarily termed "spiritual." As will be developed below, these spiritual aspects of consciousness can be accounted for by assuming that there is an overriding effect of excitation of the frontolimbic forebrain (especially that of the right hemisphere) on the dendritic microprocess that characterizes cortical synaptodendritic domains in the sensory extrinsic systems (involved in the construction of objective reality).

In addition to the gross correspondence between cortical synaptodendritic domains and the organization of sensory surfaces which gives rise to the overall characteristics of processing in the extrinsic systems, a microprocess which depends on the internal organization of each domain comes into play. As noted in Part I, this internal organization of domains embodies, among other characteristics, a spectral dimension: Synaptodendritic domains are tuned to limited bandwidths of frequencies of radiant energy (vision), sound and tactile vibration. I have reviewed this evidence extensively on a number of occasions (Pribram 1966, 1971a, 1982, 1991, Pribram, Nuwer, and Barron 1974).

As late as the 1950s, how the brain operated to make perception possible and how the effects of perceived experiences could be stored remained

enigmatic. For the most part, this was due to the fact that no one could inquire how distributed processes could operate to produce a palpable reality. Thus Karl Lashley (1950) exclaimed that his lifelong search for an encoded memory trace had been in vain, and Gary Boring (1929) indicated in his *History of Experimental Psychology* that little was to be gained, at this stage of knowledge, by psychologists studying brain function.

As noted in the Introduction to this essay, all this was dramatically changed when engineers, in the early 1960s, found ways to produce optical holograms using the mathematical formulation proposed by Dennis Gabor (1948). The mathematics of holography and physical properties of holograms provided a palpable instantiation of distributed memory and how percepts (images) could be retrieved from such a distributed store. Engineers (Van Heerden 1963), psychophysicists (Julez and Pennington 1965), and neuroscientists (Pribram 1966, and Pollen, Lee, and Taylor 1971) saw the relevance of holography to the hitherto intractable issues of brain function in memory and perception (Barrett 1969a, 1969b, Campbell and Robson 1968, and Pribram, Nuwer, and Barron 1974).

This timeless/spaceless/causeless aspect of processing is instigated by frontolimbic excitation that practically eliminates the inhibitory surrounds of receptive fields in the sensory systems (Spinelli and Pribram 1975) allowing these systems to function holistically. It is this holistic type of processing that is responsible for the apparently extrasensory dimensions of experience which characterize the esoteric traditions: Because of their enfolded property these processes tend to swamp the ordinary distinctions such as the difference between corporeal and extracorporeal reality.

The ordinary distinctions result from an enhancement of the inhibitory surrounds of the receptive fields when the systems of the posterior cortical convexity become activated (Pribram, Lassonde, and Pito 1981). As a consequence the sensory system becomes an information processing system in Shannon's sense: intentional choices among alternatives become possible. This is comparable to the process called the "collapse of the wave function" in quantum physics. By contrast, in the esoteric traditions, consciousness is not limited to choices among alternatives and is therefore "intuitive."

An intriguing and related development (because it deals with the specification of a more encompassing, "cosmic" order) has occurred in quantum physics. Over the past 50 years it has become clear that there is a limit to the accuracy with which certain measurements can be made when others are being taken. This limit is expressed as an indeterminacy. Gabor, in his description of a quantum of information, showed that a similar indeterminacy describes telecommunication: this leads to a unit of minimum uncertainty, a unit describing the maximum amount of information that can be packed for processing.

These contributions have resulted in a convergence of our understanding of the microstructure of communication—and therefore of observation—and the microstructure of matter. The necessity of specifying the

observations that lead to inferring the properties of matter has led noted physicists to write a representation of the observer into the description of the observable. Some of these physicists have noted the similarity of this specification to the esoteric descriptions of consciousness. Books with such titles as *The Tao of Physics* (Capra 1975) and *The Dance of the Wu Li Masters* (Zukav 1971) have resulted.

There is therefore in the making a real revolution in Western thought. The scientific and esoteric traditions have been clearly at odds since the time of Galileo. Each new scientific discovery and the theory developed from it has, up until now, resulted in the widening of the rift between objective science and the subjective spiritual aspects of man's nature. The rift reached a maximum toward the end of the nineteenth century: mankind was asked to choose between God and Darwin; heaven and hell were shown by Freud to reside within us and not in our relationship to the natural universe. The discoveries of twentieth-century science briefly noted here, but reviewed extensively elsewhere (Pribram 1986, 1991) do not fit this mold. For once the recent findings of science and the spiritual experiences of mankind are consonant. This augurs well for the upcoming new millennium—a science which comes to terms with the spiritual nature of mankind may well outstrip the technological science of the immediate past in its contribution to human welfare.

SUMMARY AND CONCLUSION

The varieties of conscious experience reviewed can be accounted for within the purview of science. Brain science has contributed sizably to this accounting.

States of consciousness are linked to electrochemical configurations of synaptodendritic domains; conscious processing to attention, volition and thought. The contents of consciousness fall into three major categories: (1) the construction of personal and extrapersonal objective reality by virtue of processing by systems of the posterior cerebral convexity; (2) the construction of narrative composed of episodes and eventualities as processed by the frontolimbic forebrain. Finally, (3) we distinguish a transcendental variety of consciousness that goes beyond narrative by freeing the cortical dendritic microprocess entirely from the spatiotemporal constraints so essential to the construction of personal and extrapersonal reality.

As with so many categorical constructions that we take to be unitary (for example, time, complexity, mind, brain), understanding demands deconstruction into components that appear to be only loosely connected. The puzzle is why these components are grouped together in the first place. There is some intuition that fails to be addressed by analysis. With regard to consciousness, this intuition may rest simply on the unity of experiencing—not what is experienced or how experience is generated. Rather it is that experiencing occurs. The dictionary definition of experiencing is to try, to test. This definition accounts for the affinity between consciousness and

conscience which in some languages are not distinguished. In a deep sense, therefore, consciousness occurs when some destabilizing "trying" event or series of events occurs: An interrupted action or plan; an earthquake or other unanticipated environmental challenge; a neurochemical disequilibrium of a homeostatic process. Thus, to be conscious is to experience, to be tried and to try. To paraphrase Descartes: I am tried and I try, therefore I am conscious.

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