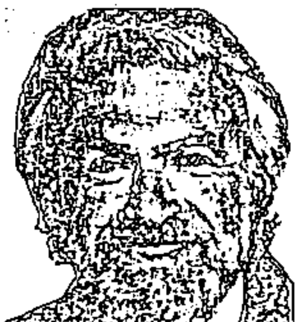
MILLENNIUM

CARL ROGERS on Communities
JONAS SALK on Human Intelligence
TIMOTHY LEARY on Science
FREDERIK POHL on Politics
KARL PRIBRAM on the Brain
JEAN HOUSTON on Education
WILLIS HARMAN on Work
HARVEY COX on Religion
MARILYN FERGUSON on Relationships
MICHAEL MURPHY on the Body
ALBERTO VILLOLDO on Healing
DONALD MANKIN on Leisure
KEN DYCHTWALD on Aging
LONNIE BARBACH on Sexuality
RICK CARLSON on Health Care
LIVIO VINARDI on Art
STANLEY KRIPPNER and
ARTHUR HASTINGS
on Parapsychology
BARBARA MARX HUBBARD
and BARRY McWATERS
on Human Evolution

Glimpses into the 21st Century

Original Essays by Eminent Thinkers Explore the World of Tomorrow

Edited by
ALBERTO VILLOLDO and
KEN DYCHTWALD



Throughout his inventive and colorful career, Dr. Karl Pribram has distinguished himself as a scientist, physician, and brain researcher. There are few, if any, people alive who have contributed more to our understanding of the brain.

An ambitious student, Pribram gained both his B.S. and M.D. degrees in less than five years at the University of Chicago. After a residency in neurosurgery, he joined renowned brain scientist Dr. Karl Lashley at the Yerkes Laboratory of Primate Biology near Jacksonville, Florida. He served in the position of neurosurgeon on Lashley's research team while simultaneously helping to write up more than thirty years of Lashley's monumental research on the nature of memory. These early experiences sharpened Pribram's interest in the nature of the mind while developing his skills as a surgeon. In fact, it was the wedding of Pribram's varied talents that eventually gave birth to the hybrid field now known as neuropsychology.

After a short term as director of the Yerkes Laboratory following Lashley's retirement, Pribram went on to Yale, where during his ten-year stay he taught courses in neurophysiology and physiological psychology while continuing his research into the workings of the human brain. After leaving Yale, he joined the faculty at Stanford University, where for the past twenty years he has served as professor of neuroscience in the Departments of Psychology, Psychiatry, and Behavioral Sciences.

Throughout his life, Dr. Pribram has repeatedly been in the forefront of brain/mind studies. In the early 1950s his discoveries of the nature of the brain's limbic system forced a complete restructuring of existing knowledge about mental functioning. Again in 1960 his findings refuted popular behaviorist views of brain function. Pribram's innovative research in collaboration with George A. Miller and Eugene Gallanter proved that brain cells do not work as a simple reflex arc, but instead are part of a sophisticated feedback loop. Declaring themselves "subjective behaviorists," the three scientists gave impetus to the cognitive movement, now one of the dominant fields in psychology.

In recent years, Pribram's studies and research have taken an entirely new and somewhat startling turn. Proposing that the brain does not function in a linear fashion, as has always been believed, but instead functions more like a hologram, Pribram has caused his greatest scientific stir to date. In the following essay Dr. Pribram uses his own history as a brain pioneer to demonstrate the dramatic ways in which our understanding of human behavior has broadened and deepened in recent years.

KARL PRIBRAM

THE BRAIN

Recent scientific endeavor has been characterized by a peculiar happening: While laboratory scientists have been learning more and more about less and less, the impact of their findings has repeatedly scuttled reductionistic theories in favor of more encompassing holistic views. This trend has accelerated to such an extent that I see a major paradigm shift taking place in all of science.

In *Structure of Scientific Revolutions* (1962), Thomas Kuhn pointed out that much of everyday scientific effort is directed toward substantiating major world views, theories that have become established in various fields of inquiry. However, from time to time the weight of evidence demands revision of these views. At this point, fresh views have a chance to overturn the old, provided they can satisfactorily explain those very irritating points that produced difficulties for the older theories.

Three such revolutions in thought have occurred during my research career, and I was privileged to be in the center of the storms that always surround such upheavals. In each instance, the revolution—the overturning of then currently established thought—took us back to earlier, perhaps more basic formulations. However, where the earlier views had been vague and general, the new theories took on great precision and became instrumental for gathering the data that comprises most of any scientific effort.

The first revolution came about when the conception of a horizontally organized central nervous system in which higher levels simply control lower levels was replaced by a concentric view in which the core and outer portions of the nervous system perform different functions. The second revolution replaced the reflex arc with a self-regulating elementary behavioral unit. Thus a linear, causal, and stimulus-response behavioral science gave way to an understanding of the nervous system and behavior based on feedback and feedforward organizations. Finally, a model of a distributed memory store was achieved, giving rise to a precise, mathematical, holistic formulation that had heretofore been completely lacking in science.

REVOLUTION I: THE COREBRAIN AND THE CHEMICAL CONTROL OF CONSCIOUSNESS

The first of these revolutions came as a result of innovations in the study of brain function after World War II.

The overall configuration of the brain is much like that of a mushroom—a stem with an umbrellalike outer layer or cortex. Early investigators analyzed brain function by dividing the cortex from the brainstem and by "cutting" the stem at various intervals. Principles of organization were noted: the top levels regulate complex experience and behavior, while the lower levels regulate more automatic and reflex processing. Further, the higher levels act upon lower levels essentially by inhibiting the more or less continuous neural discharge. Just as the heart beats spontaneously (in fact, it does so because of the discharging of its neural system), so do many nerve cells "beat" continuously throughout the life of the organism. When the controls from above are severed, the spontaneous discharge becomes excessive and reflexes run loose, producing spasticity and disorganization.

Since World War II, this rather simple view of the organization of the brain, brainstem, and spinal cord has been augmented by more sophisticated approaches. The brainstem and spinal cord are now seen not as the stem of a mushroom, but rather as a stalk of celery. Similarly, the umbrellalike top of the brain is now studied not as a homogeneous organ but more as if it were layered like an onion. Thus, the functions of the outer shells can be contrasted with those of the inner core in both the brainstem and the brain.

When the core portions of the brain are injured or stimulated in some special way, changes in the individual's emotional state occur. A most dramatic illustration of such changes occurred in a patient who had suffered a bullet injury during World War II. The bullet had lodged within the ventricles of the brain and would float about in the fluid-filled cavities. Depending on which way the patient held his head for a period of time, he would experience sadness or elation and all of the concomitant behavior that attends profound changes in emotional state.

The advent of psychotropic drugs has generated an outpouring of studies that relate changes in emotion to the chemistry of the core parts of the brain and brainstem. These studies have shown that not only emotional and motivational states, but also one's feelings of effort and comfort and the integration of experience into memory are a function of the chemistry of these systems. States of consciousness thus devolve in a large measure on the neurochemical processes of the core brain. A considerable number of these processes are being investigated. I will here focus on three of special interest that are beginning to comprise a coherent body of knowledge.

One such system converges forward onto the amygdala, an almond-shaped accumulation of nerve cells deeply buried in the lobe of the brain. (*Amygdala* is a Greek word meaning "almond." Having removed hundreds of amygdala from monkeys, I was startled to hear street vendors in Athens hawking their wares: "Amygdala! Amygdala!") Removal of the amygdala in monkeys produces marked changes in the animal's reaction to abrupt environmental change. Such reactions are called orienting reactions and as a rule are brief, such as the startle reaction when we are interrupted by a novel sound or flash. When the sound (or flash) is repeated, the reaction progressively diminishes as we become accustomed to it. The manifestations of orienting such as turning toward the sound reaction are accompanied by visceral responses, many of them mediated by the autonomic nervous system. Removal of the amygdala disturbs the entire pattern of orienting and habituation.

This disturbance of the orienting reaction is a part of a larger pattern of changes in emotional reactions—reactions that can most easily be remembered as the 4 F's: Feeding, fighting, fleeing and sex. The changes are in each instance very specific—once begun, the behavior of the animals subjected to amygdalectomy does not stop as readily as in the ordinary course of events. One group of experiments has shown that the chemistry of the amygdala modulates the mechanisms that usually signal satiety.

To summarize—the amygdala deals with the interruption of ongoing behavior—interruptions due to interest in sex or food, to sudden events that might prove dangerous, and the like. Whenever ongoing behavior is stopped or is to be stopped, the amygdala and its system become involved, and we ordinarily label such involvement as an emotional or affective reaction.

But what about ongoing behavior per se? What keeps it going in whatever direction it is headed? A different core brain system is involved, this one centered on the basal ganglia of the forebrain. The basal ganglia have for a long time been known to regulate postural and thus muscular attitudinal sets (i.e., motivation). More recently, work in my laboratory and in others has shown these structures to be involved in attention (experiential attitudinal sets)—as well as in motivation. Furthermore, the basal ganglia systems are the locus of the origin of Parkinsonism, a disease which yields to a recently discovered treatment by dopamine, a chemical found almost uniquely in these neural systems.

The amygdala and basal ganglia systems do not function in isolation. A third, and perhaps the most interesting, system coordinates the motivational "go" of ongoing behavior with the emotional "stop" of interruption. This third system intimately involves the hippocampus—an elongated structure just behind the amygdala in the human brain that looks much like a seahorse (Hippocampus in Greek) when dissected free from the brain. Our research has indicated that this coordinating system regulates attention in the sense that an organism is constantly balancing ongoing activity against distraction. The coordination apparently takes *effort* whenever a situation occurs which is beyond the experience of the organism: He must "pay" attention.

The chemistry of this system is a focus of current interest. The hippocampus selectively absorbs a substance produced by the outer portion of the adrenal gland—a chemical that is secreted whenever the organism is under prolonged stress. This secretion is regulated by another from the pituitary "master" gland—and once again the hippocampal system shows special sensitivities to this chemical and its near relatives. What is most interesting, however, is that these pituitary secretions can protect the organism against pain and suffering much as does the drug morphine. An extremely active area of research at the moment concerns isolating a family of morphine-like substances secreted not only by the pituitary gland (the enkephalins) but by many nerve cells in the core brain systems.

These startling discoveries suggest that we are all "addicts" in a sense—but that our "addiction" is internally regulated for most of us. Our ordinary state of consciousness is not so ordinary, it seems, so perhaps we should not view alternate states as so extraordinary.

Thus, the earlier theories of hierarchical control of "lower centers" by "higher brain functions" have been radically modified. Hierarchical control has not been done away with—as we shall see in the next section. Rather, it has been shown to be more limited than earlier theories had held and the substrates—the "lower centers"—have been shown to have a much richer complexity than had been suspected. It is the chemical and physiological organization of these core structures of the brain that in fact exercise primary control, and the "higher functions" only modify and modulate these lower levels.

When these studies began, only the hypothalamic region was viewed as a central control mechanism for emotional and motivational behaviors, and this in the earlier tradition as the "head ganglion of the autonomic nervous system." Walter Cannon's classical studies at Harvard University during the 1920s and 1930s had established the principle of homeostasis as describing hypothalamic function. The work of Horace Magoun and Donald Lindsley at the University of California at Los Angeles brought the core of the lower brain stem—the reticular formation—into prominence during the 1950s. And the studies accomplished at Yale by Paul MacLean and myself during the same period showed that these core brain functions extended forward to the (limbic) forebrain, as well.

The suggestion that this portion of the forebrain—and the core brain as a whole—might regulate conscious states, though acceptable to neuroscientists, was certainly not even venturable in experimental psychology until the recent past (1970s). A strict behaviorism which excluded all mind-talk held sway until 1960. How this change has come about is the topic of the next section.

REVOLUTION II: THE ORGANIZATION OF BEHAVIOR

The revolution of 1950 which I have briefly reviewed above produced a change in the way we conceptualize gross brain function. We replaced the concept of centers with that of systems. And we replaced the upstairs *vs* downstairs organizational scheme with the concentrically layered approach to these systems. These changes in thinking and new accumulations of data ushered in another revolution which in my experience culminated with the publication of *Plans and the Structure of Behavior* (authored by George Miller, Eugene Galanter, and Karl Pribram) in 1960. This revolution changed our conception not so much of the organization of the brain as it changed our views about the organization of behavioral processes.

Since Descartes the reflex has been the unit of analysis of behavior. Early in the century Sir Charles Sherrington proposed, on the basis of his own experiments and the earlier ones of Bell and Magendie, that the reflex, at least at the spinal level, is an arc composed of an input neuron, an interneuron and an output neuron. Behaviorists were delighted with this simple model and attempted to build a science on this foundation: a stimulus-response psychology that could define its constructs by operations on the input (stimulus) and output (response). What could not be accounted for directly would be inferred as an intervening variable (a presumed function of interneurons). Precise particulate minitheories were developed upon these premises and even larger conceptual frames such as those of Hull and Spence were attempted.

Two major experimental results emerged during the 1950s that were difficult to contain in stimulus-response terms. The first of these was the finding by Miller and Stevenson at Yale that rats with hypothalamic lesions would overeat and become obese in an ad libidum feeding situation but would starve if they had to work even slightly for their food. Any theory based on a stimulus-provoked "drive" simply had no plausible explanation for such results. By contrast, a concept of "effort" related to some brain representation of the work involved in eating and metabolizing could readily account for the data. But "effort," a term linked to the subjective realm, was taboo to behaviorists and so the finding remained unexplained—though not unheeded by experimentalists.

The second major finding was that a large portion of the output fibers from the spinal cord to muscles ended not on contractile tissue but on muscle *receptors*. These receptors are connected in parallel with muscle tissue and serve to gauge tension. The finding that the receptors could be influenced by a signal from the central nervous system (including the brain as well as by changes in muscular tension made it necessary to totally revise our ideas about the organization of the reflex.

Sherrington had, in fact, invented the reflex arc as a simplification in

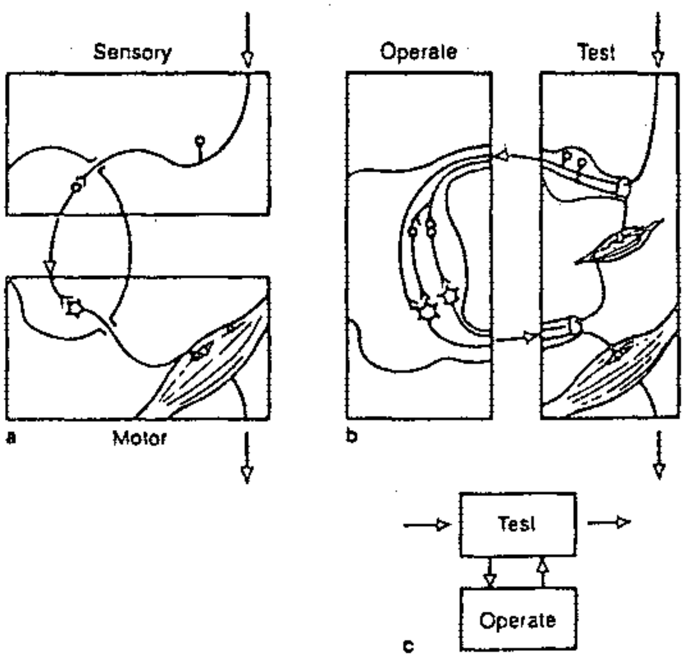


FIGURE 1. Development of the TOTE from the reflex arc concept. Note that the γ-connectivity of the muscle spindle demands that a "test" be performed.

an attempt to understand the interaction among reflexes. He never meant the "arc" to become neurophysiological or behavioristic dogma on which a whole scientific enterprise should be built:

> A simple reflex is probably a purely abstract conception, because all parts of the nervous system are connected together and no part of it is probably ever capable of reaction without affecting and being affected by various other parts, and it is a system certainly never absolutely at rest. But the simple reflex is a convenient, if not a probable, fiction.

Believers in the reflex arc fiction had to face the evidence that these receptors could be influenced by a signal from the brain as well as by the environment. Obviously the simplest, most direct modification of Sherrington's fiction is to add the output fibers from the central nervous system to the receptor. The consequences of this apparently minor revision are far from trivial. Imagine for a moment that, isolated from other stimulation, you are monitoring receptor activity. When a change occurs, how will you know whether that change is the result of an event outside the organism or an activity within the central nervous system? Some computation, some test must be applied to discern "reality"—i.e., a stimulus originating outside the organism (Figure 1).

Much behavioral evidence supports the concept that some sort of active test is performed on input. Many of the pertinent observations result from experiments in which the visual image is distorted or inverted by prism glasses worn by the subject for a prolonged time. Given an opportunity to move about and manipulate his environment, that person can right his perceptual world in a matter of hours or days (depending on the extent of the distortion). Should such manipulation or movement be proscribed, however, there is considerable delay in the correction of the distortion if it can be accomplished at all. The manipulative experience appears integral to some phase of the construction of the corrective mechanism.

A generalized diagram of the reflex, the unit of neurobehavioral analysis, can therefore be attempted (see TOTE Fig. 2). To be effective, input must be compared to and tested against central neural activity; the results of this comparison initiate some operation which then influences either other parts of the nervous system, or the external world, as in the manipulation of the environment in the prism experiment above. The consequences of this operation are then fed back to the comparator and the loop continues until the test has been satisfied—until some previous setting, indicative of a state-to-be-achieved, has been attained (exit).

This modification of the reflex arc results in a diagram familiar to engineers. Tracking devices of various sorts are built to just such specifications. The apparatus, known as a servomechanism, matches the effects of

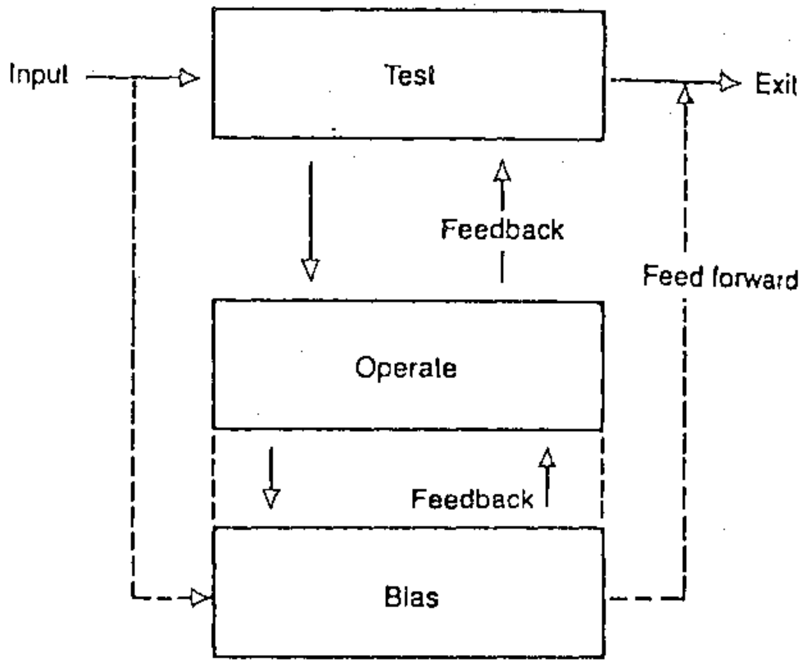


FIGURE 2. The TOTE servomechanism modified to include feed-forward. Note the parallel processing feature of the revised TOTE.

an input against the effects of the outcome of an activity aimed to deal with that input. The thermostat is probably the most familiar servomechanism.

The reflex arc was a conception used by Sherrington to explain data he had before him. The success of his explanations made the reflex arc an extremely useful fiction. The TOTE diagram is also a fiction when applied to neurobehavioral analysis. It is a somewhat higher-order fiction than the reflex arc—the reflex arc is the limiting case of a servo in which feedback can be accomplished only via the organism's environment and in which the operation performed is insensitive even to this feedback, i.e., the effect, once initiated, runs itself off to a predetermined state. The usefulness of a higher order fiction must lie in its ability to handle a broader range of facts. The TOTE concept was brought to bear for just this reason: the reflex arc cannot encompass the data that demonstrate the central control of receptor mechanisms.

The essence of the change from the reflex arc to the TOTE is the Test mode. The test implies an active comparison between input and some central state—a state that can be updated by the consequences of behavior. The state therefore becomes in some sense a *representation* of the environment with which the organism interacts. In opposition to behaviorists, Gestalt and other psychologists (such as psychophysicists) less averse to taking into account reports of subjective experience had always emphasized the importance of representational mechanisms (maps, schemata, neural processes isomorphic to stimuli, etc). In *Plans and the Structure of Behavior* we also drew upon representations and worked out the implications for psychology of the then recent neurobehavioral and neurophysiological findings. The reviews of the book were almost all dismal ("...unfortunate that such hardheaded scientists have gone soft—is it their age or the California climate where the book was written?"). But for many years every president of the American Psychological Association and recipient of the Association's prize for scientific contributions mentioned the book as seminal to their own thinking—and almost two decades of experiments by cognitive psychologists attest to the vigor of the conceptions put forward.

This favorable response was in part due to the fact that our proposal used the digital computer as a model for the processes we were describing. Thus experimentalists could for the first time perform *in vitro* tests in the behavioral sciences—types of experiments abstracted from life situations that have proved so invaluable in the work of biochemists. So much of academic psychology is now cognitive that one can safely say a revolution in thinking has occurred. But as noted earlier, revolutions simply overturn the present in favor of an earlier, less articulated past. The initial behaviorist revolution was responsible for making psychology an operational science that brought quantitative experiment to bear on psychological problems. The cognitive revolution simply readmitted reports of subjective experience to this quantitative scientific enterprise (we first called ourselves subjective behaviorists, before the cognitive label became the more common).

REVOLUTION III: THE HOLOGRAM AND THE ORGANIZATION OF EXPERIENCE

The computer is not, however, the only artifact that has proved useful in allowing *in vitro* experimentation to occur in the brain and behavioral sciences. Computers provide the key to the way in which TOTEs (feedback units, homeostats) can be assembled into higher order control operations, the operate part of the TOTE. Computers do not furnish the tools for understanding the organization of the test portions of the TOTE, the representational mechanism and its interaction with input.

New data and novel artifacts contributed towards producing the current 1970's revolution in thinking. This revolution may be the most far-reaching, since it encompasses not only the brain and behavioral sciences but the physical sciences as well.

The new data concern the mechanisms of perception of the physical world. Over a century ago, Georg Ohm—who is responsible for the ohm as a measure of electrical resistance—suggested that the ear and the auditory brain analyze the periodicities of sound waves. Herman Helmholtz provided evidence for this view of the auditory system as a wave form analyzer. More recently, evidence obtained by Fergus Campbell and John Robson and their associates at Cambridge University (and by others at Harvard, Berkeley, and our own Stanford laboratories) indicates that pattern vision may also be based on wave form analysis. In vision the wave forms are made up of light and dark regions over *space* (rather than over time as in the auditory system). The complex of frequencies of alternating light and dark (called the "spatial frequencies") is analyzed (decomposed into its fundamental frequencies) much as a complex sound is registered in distinct melodies and harmonies by the auditory system.

The importance of a wave form analytic mechanism in brain function appears not to be limited to hearing and seeing. Bekesy showed, with a brilliant series of demonstrations (akin to the demonstration of a stereo effect when the phase of the frequencies of two loudspeakers is properly adjusted), that the touch (and perhaps even the taste) systems also operate in this fashion. Thus our perception of the physical world is dependent on a brain mechanism that processes wave forms—vibrations of occurrences (over time and space and perhaps other dimensions).

The novel artifact in this third revolution is the hologram, a photographic process that stores the wave forms generated when light falls on an object rather than simply storing the intensity reflected by that object as in ordinary photography. Storing the wave fronts encodes the relationships between their frequencies (their phase) in addition to intensity information. Thus when properly illuminated, the hologram reconstructs a three-dimensional image of the original object. Interestingly, this image is constructed at a plane remote from the photographic film (as in stereophonic reproduction of music). Looking at the film without proper illumination shows only a relatively haphazard (random-appearing) distribution of developed silver grains.

The hologram derives its name from another interesting property, every reasonably sized part of the hologram encodes the entire image. Essentially the hologram is a blurred record—the light reflected by any and every point of a scene is spread over the entire film surface. The blur is not as haphazard as it appears to be, however, but is akin to the wave fronts produced in a pond by a pebble. If one could momentarily freeze a pond into which several pebbles had simultaneously been thrown, one could "reconstruct" the site of impact of the pebbles from the waves that had been generated. In a similar fashion image reconstruction from a hologram deblurs the information by decoding the encoded wave forms. Mathematically the encoding and decoding are inverse transforms of each other, that is, the same operation of wave form analysis produces both the blur (by spreading the information) and the image (by reconstruction).

Thus, in addition to helping us understand perception, the evidence that the brain mechanisms of perception involve wave form analysis helps explain something that has been a puzzle to students of brain function for a long time: the distributed nature of the memory trace. Even with massive brain lesions, specific memories are never lost in isolation. For example, if a person has a stroke and half of his brain is inoperative, he does not recognize only half of his children. Memories are not localized to specific regions.

If sensory coding is done by means of wave form analysis, the problem is solved. The input is automatically distributed across a small part of the brain cortex as a series of interfering wave front patterns. This is to say that when an input is analyzed by a two-dimensional frequency transform, this information is automatically (or axiomatically by virtue of the process) distributed in the form of a hologram.

There are certain important consequences of this new model of cortical brain function. First of all, as we have noted, it explains a great deal about brain function that until now has been inexplicable. Second, in holography we are storing information in a form that does not have a space-time dimension. What is stored is everywhere and records only frequency of occurrence—not place or time—although space and time can be reconstructed from the stored information.

I was once asked how it is that an image can be reconstructed from memory when its holographic-like representation is, so to speak, spread over large extents of brain cortex. Where and who is the little man doing the reconstructing? It finally occurred to me that not only was I not going to be able to answer that question, but that it might be the wrong question to ask. A more appropriate question seemed to be: What makes us believe that we see things the way they are? The lens of the eye focuses the world of light on the retina, producing an image and then, through the processing that we have been discussing, the brain dismembers this image. So let us ask: *What* is the nature of the world of light that the lens is focusing? What would we experience if we used other ways of viewing the world than through lenses? Quite possibly the world outside might appear to us as a hologram. In fact, many physicists (e.g. Heisenberg, Bohr, Wigner, Bohm, to mention a few of the most outstanding) who have been struggling to understand the fundamental nature of matter have proposed just such a possibility.

In suggesting this, I am not forgetting classical mechanics and the "objective" view of the ordinary sensory universe. However, this "objective" view can only partly account for observations at the ultramacro and ultramicro levels. As David Bohm has pointed out, since Galileo science has essentially taken its view of both the macro-universe and the micro-universe through lenses. When, however, science uses other procedures (such as looking at the world through interferometers), we obtain different results. Perhaps we have focused far too long on one type of organization while ignoring other possible types.

All this has direct implications for an understanding of the physical as well as the psychological universe. We in the Western world are just beginning to be aware that there might be several orders that characterize the universe. If holographic representations *within* the brain do not exist in terms of the familiar space-time coordinates, then perhaps there are orders of the universe *outside* that also do not exist in ordinary space-time. Leibniz called such an order monadic. His conception derived from the mathematics he had invented—or discovered—the integral calculus which in Gabor's hands led to the invention of the hologram—a set of spread functions that would aid the recording of interference patterns (spatial frequencies). The hologram and its predecessor the monad were initially mathematical inventions and occurred long before current technology made possible the artifacts we now use.

What makes holographic theory so revolutionary is the fresh view that the wave form domain brings to all of science. Wave "numbers" can refer to densities of occurrences with respect to any number of dimensions other than or in addition to time-space. This could mean that physical orders exist in which synchronicity rather than causality operates as a basic principle. Encoding in the wave form domain gives the appearance of random distributions, but with the appropriate transforms this apparent randomness can be decoded into ordinary perceptible forms. This could mean that beyond every appearance of randomness lies hidden an order that awaits discovery.

The hologram is holistic in that every part represents the whole and the whole is represented in all its parts. This holistic organization distinguishes it from others in which the whole is considered to be more than or different from the sum of its parts. Holism derived from holograms describes an enfolded order which can be readily unfolded into the ordinary sensory order produced by lenses and lens-like receptors. The enfolding and unfolding transformations are the product of a highly precise mathematical operation, even more precise and predictable than the statistical probability operations that now form the hard core of ordinary scientific calculations. Does this not augur for a paradigm shift in all of science? Suddenly holism becomes respectable.

My experience, as I have recounted it here, may be idiosyncratic. But I do not believe it is. Rather, I find it significant that every time a series of precise data has accumulated, it has overturned theories that seemed up to that time extremely precise in formulation, and replaced them with more holistic theories that up to then had been less well articulated. I have thus begun to suspend disbelief in more holistic views even when they cannot be completely understood on the basis of available data. One never knows when the tacit knowledge that produced these views will become explicit because of better technology or inventive thought. Further, I have come to suspect that scientific procedure in the near future will shed light not only on the physical and biological universe, as it has in the past, but on the psychological and even *spiritual*, as well. After all, mathematics is a psychological process that underlies all of science, and mathematical insights have proved not altogether different from spiritual ones—as for example Leibniz' monads. The extensive changes in human material weal that science thus far has brought may thus be only a prelude to even more profound influences in a realm that heretofore was considered outside the purview of science.