least cost ration problems. Information about kinds of programs available and their use is detailed in B. F. Lanpher, Ed., *Inventory of EDP programs used in Agricultural Extension* (Extension Service, Department of Agriculture, Washington, D.C., 1973). Initial efforts in use of computers for real-time forecasting are described in R. T. Huber and R. L. Giese, *Proc. North Cent. Branch Entomol. Soc. Am.* **28**, 139 (1973).
12. We presented these concepts in verbal and written form as a part of a cropping system proposal to officials of the USDA in September 1971. Represented were the Extension Service, Cooperative States Research Service, Animal and Plant Health Inspection Service, and Agricultural Research Service.
13. A. B. Clymer, *Simulation* **15**, 50 (1970).
14. G. E. Miles, *Purdue Univ. Agric. Exp. Sta. Bull. No. 50* (1974).
15. J. A. Witz, *Agric. Sci. Rev. Coop. State Res. Serv. U.S. Dep. Agric.* **11**, 37 (1973).
16. For a more complete description of the plant simulation, see G. E. Miles, R. J. Bula, D. A. Holt, M. M. Schreiber, R. M. Peart, *ASAE (Am. Soc. Agric. Eng.) Pap. No. 73-4547* (1973).
17. G. E. Miles, T. R. Hintz, A. B. Pritsker, M. C. Wilson, R. M. Peart, in *Proceedings of the 5th Annual Pittsburgh Conference on Modeling and Simulation* (University of Pittsburgh, Pittsburgh, Pa., 1974), pp. 1157–1161; G. E. Miles, R. M. Peart, R. J. Bula, M. C. Wilson, T. R. Hintz, *ASAE (Am. Soc. Agric. Eng.) Pap. No. 74-4022* (1974).
18. D. L. Haynes, R. K. Brandenburg, P. D. Fisher, *Environ. Entomol.* **2**, 889 (1973).
19. The acronym MIRACLE stands for multidisciplinary integrated research activities in complex laboratory environments. This is discussed in greater detail in R. B. Harrington and R. L. Giese, *Proc. Fed. Exp. Biol.* **33** (No. 12), 2393 (1975); D. C. Beckwith, *Am. Lab. (Greens Farms, Conn.)* **5**, 77 (1973).
20. R. M. Peart, R. T. Huber, W. H. Blake, D. R. Wolf, G. E. Miles, *ASAE (Am. Soc. Agric. Eng.) Pap. No. 74-5043* (1974).
21. We express appreciation for principal contributions in this integrated team effort to R. J. Bula (plant physiology), C. R. Edwards (Entomology Extension), R. B. Harrington (MIRACLE Computing Center), T. R. Hintz (insect impact), D. A. Holt (plant physiology), G. E. Miles (systems analysis), and M. C. Wilson (insect population dynamics). The Purdue Alfalfa Pest Management project is sponsored by the Purdue Agricultural Experiment Station, the USDA Agricultural Research Service (Agreement No. 12-14-3001-218), and the USDA Animal and Plant Health Inspection Service and Extension Service (Agreement No. 12-16-100-150). This article is approved for publication by the director of the Purdue Agricultural Experiment Station as Journal Paper No. 5627.

Limits to the Scientific Understanding of Man

Human sciences face an impasse since their central concept of the self is transcendental.

Gunther S. Stent

For the past two centuries scientists, particularly in English-speaking countries, have generally viewed their attempt to understand the world from the epistemological viewpoint of positivism. All the while, positivism had been under attack from philosophers, but it is only since the 1950's that its powerful hold on the students of nature finally seems to be on the wane. There is as yet no generally accepted designation for the philosophical alternatives that are replacing positivism, but the view of man known as "structuralism," which has informed certain schools in the human sciences, appears to be central to the latter-day epistemological scene (*1*). As I shall try to show in this article, in addition to the philosophical and psychological arguments that have been advanced in its behalf, structuralism can draw support also from biological insights into the evolutionary origins and manner of function of the brain. But whereas the work of structuralist scientists has shown up the essential barrenness of the positivist approach to human behavior, even the structuralist program, however meritorious, is unlikely to lead to a scientifically validated understanding of man.

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Positivism

The principal tenet of positivism, as formulated in the 18th century mainly by David Hume and the French Encyclopaedists, is that, since experience is the sole source of knowledge, the methods of empirical science are the only means by which the world can be understood (*2*). According to this view, the mind at birth is a clean slate on which there is gradually sketched a representation of reality built on cumulative experience. This representation is orderly, or structured, because, thanks to the principle of inductive reasoning, we can recognize regular features of our experience and infer causal connections between events that habitually occur together. The possibility of innate or a priori knowledge of the world, a central feature of the 17th-century rationalism of René Descartes, is rejected as a logical absurdity.

It is unlikely that the widespread acceptance of positivism had a significant effect on the development of the physical sciences, since physicists have little need to look to philosophers for justification of their research objectives or working methods. Moreover, once a physicist has managed to find an explanation for some phenomenon, he can be reasonably confident of the empirical test of its validity. For instance, the positivist rejection of the atomic theory in the late 19th century, on the grounds that no one had ever "seen" an atom, did not stop chemists and physicists from then laying the groundwork for our present understanding of microscopic matter. However, in the human sciences, particularly in psychology and sociology, the situation was quite different. Here positivism was to have a most profound effect. One reason for this is that practitioners of the human sciences are much more dependent on philosophical support of their work than are physical scientists. In contrast to the clearly definable research aims of physical science, it is often impossible to state explicitly just what it really *is* about human behavior that one wants to explain. This in turn makes it quite difficult to set forth clearly the conditions under which any postulated causal nexus linking the observed facts could be verified. Nevertheless, positivism helped to bring the human sciences into being in the first place, by insisting that any eventual understanding of man must be based on the observation of facts, rather than on armchair speculations. But, by limiting inquiry to such factual observations and allowing only propositions that are based on direct inductive inferences from the raw sensory data, positivism constrained the human sciences to remain taxonomic disciplines whose contents are largely descriptive with little genuine explanatory power. Positivism clearly informed the 19th-century founders of psychology, ethnology, and linguistics. Though we are indebted to these founders for the first corpus of reliable data concerning human behavior, their refusal to consider these data in terms of any propositions not derived inductively from direct observation prevented them from erecting a theoretical framework for understanding man.

Structuralism

Structuralism transcends the limitation on the methodology, indeed on the agenda of permissible inquiry, of the human sciences imposed by positivism. Structuralism admits, as positivism does not, the possibility of innate knowledge not derived from direct experience. It represents, therefore, a return to Cartesian rationalist philosophy. Or, more exactly, structuralism embraces this feature of rationalism as it was later reworked by Immanuel Kant for his philosophy of critical idealism. Kant held that the mind constructs reality from experience by use of innate concepts, and thus to understand man it is indispensable to try to fathom the nature of his deep and universal cognitive endowment. Accordingly, structuralism not only permits propositions about behavior that are not directly inducible from observed behavioral data, but it even maintains that the relations between such data, or *surface structures*, are not by themselves explainable. According to this view the causal connections that determine behavior do not relate to surface structures at all. Instead, the overt behavioral phenomena are generated by covert *deep structures*, inaccessible to direct observation. Hence any theoretical framework for understanding man must be based on the deep structures, whose discovery ought to be the real goal of the human sciences.

Probably the best known pioneer of structuralism is Sigmund Freud, to whom we owe the fundamental insight that human behavior is governed not so much by the events of which we are consciously aware in our own minds or which we can observe in the behavior of others, but rather by the deep structures of the subconscious which are generally hidden from both subjective and objective view. The nature of these covert deep structures can only be inferred indirectly by analysis of the overt surface structures. This analysis has to proceed according to an elaborate scheme of psychodynamic concepts that purports to have fathomed the rules which govern the reciprocal transformations of surface into deep and of deep into surface structures. The great strength of Freudian analytical psychology is that it does offer a theoretical approach to understanding human behavior. Its great weakness, however, is that it is not possible to verify its propositions. And this can be said also of most other structuralist schools active in the human sciences. They do try to explain human behavior within a general theoretical framework, in contrast to their positivist counterparts who cannot, or rather refuse to try to do so. But there is no way of verifying the structuralist theories in the manner in which the theories of physics can be verified through critical experiments or observations. The structuralist theories are, and may forever remain, merely plausible, being, maybe, the best we can do to account for the complex phenomenon of man.

Ethnology and Linguistics

For instance, positivist ethnology, as conceived by one of its founders, Franz Boas, sought to establish as objectively and as free from cultural bias as possible the facts of personal behavior and social relations to be found in diverse ethnic groups. Insofar as any explanations are advanced at all to account for these observations, they are formulated in functionalist terms. That is to say, every overt feature of behavior or social relation is thought to serve some useful function in the society in which it is found. The explanatory work of the ethnologist would be done once he has identified that function and verified its involvement by means of additional observations. Accordingly, the general aim of this approach to ethnology is to show how manifold and diverse the ways are in which man has adapted his behavior and social existence to the range of conditions that he encountered in settling the earth. By contrast, structuralist ethnology, according to one of its main exponents, Claude Lévi-Strauss, views the concept of functionality as a tautology, devoid of any real explanatory power for human behavior. All extant behavior is obviously "functional" since all "disfunctional" behavior would lead to the extinction of the ethnic group that exhibits it. Instead of functionality, so Lévi-Strauss holds, only universal and permanent, deep structural aspects of the mind can provide any genuine understanding of social relations. The actual circumstances in which different peoples find themselves no more than modulate the overt behavior to which the covert deep structures give rise. In other words, the point of departure of structuralist ethnology is the view that the apparent diversity of ethnic groups pertains only to the surface structures and that at their deep structural level all societies are very much alike. Hence, the general aim of structuralist ethnology is to discover those universal, deep mental structures which underlie all human customs and institutions.

Positivist linguistics, as conceived by its founders, such as Ferdinand de Saussure and Leonard Bloomfield, addresses itself to the discovery of structural relations among the elements of spoken language. That is to say, the work of that school is concerned with the surface structures of linguistic performance, the patterns which can be observed as being in use by speakers of various languages. Since the patterns which such classificatory analysis reveals differ widely, it seemed reasonable to conclude that these patterns are arbitrary, or purely conventional, one linguistic group having chosen to adopt one, and another group having chosen to adopt another convention. There would be nothing that linguistics could be called on to explain, except for the taxonomic principles that account for the degree of historical relatedness of different peoples. And if the variety of basic patterns of various human languages is indeed the result of arbitrary conventions, study of extant linguistic patterns is not likely to provide any deep insights into any universal properties of the mind. By contrast, the structuralist approach to linguistics, according to its main modern proponent, Noam Chomsky, starts from the premise that linguistic patterns are not arbitrary. Instead, all men are believed to possess an innate, a priori knowledge of a universal grammar, and that despite their superficial differences, all natural languages are based on that same grammar (*3*). According to that view, the overt surface structure of speech, or the organization of sentences, is generated by the speaker from a covert deep structure. In his speech act, the speaker is thought to generate first his proposition as an abstract deep structure that he transforms only secondarily according to a set of rules into the concrete surface structure of his utterance. The listener in turn fathoms the meaning of the speech act by just the inverse transformation of surface to deep structure. Chomsky holds that the grammar of a language is a system of transformational rules that determines a certain pairing of sound and meaning. It consists of a syntactic component, a semantic component, and a phonological component. The surface structure contains the information relevant to the phonological component, whereas the deep structure contains the information relevant to the semantic component, and the syntactic component pairs surface and deep structures. Hence, it is merely the phonological component of grammar that has become greatly differentiated during the course of human history, or at least since the construction of the Tower of Babel. The semantic component has remained invariant and is, therefore, the "universal" aspect of the universal grammar, which all natural languages embody. And this presumed constancy through time of the universal grammar cannot be attributable to any cause other than an innate, hereditary aspect of the mind. Hence, the general aim of structuralist linguistics is to discover that universal grammar.

Transcendental Concepts

Now, in retrospect, at a time when positivism and its philosophic and scientific ramifications appear to be moribund, it seems surprising that these views ever did manage to gain such a hold over the human sciences. Hume, though one of its founders, already saw that the positivist theory of knowledge has a near-fatal logical flaw. As he noted, the validity of inductive reasoning—which, according to positivism forms the basis of our knowledge of the regularity of the world, and hence for our inference of causal connections between events—can neither be demonstrated logically nor can it be based on experience. Instead, inductive reasoning is evidently something that man brings to rather than derives from experience. Not long after Hume, Kant showed that the positivist doctrine that experience is the sole source of knowledge derives from an inadequate understanding of the mind. Kant pointed out that sensory impressions become experience, that is, gain meaning, only after they are interpreted in terms of a priori concepts, such as time and space. Other a priori concepts, such as induction (or causality) allow the mind to construct reality from that experience. Kant referred to these concepts as "transcendental," because they transcend experience and are thus beyond the scope of scientific inquiry. But why was it that, although Kant wielded an enormous influence among philosophers, his views had little currency among scientists? Why did positivism rather than Kant's "critical idealism" come to inform the explicit or implicit epistemological outlook of much of 19th- and 20th-century science? At least two reasons can be advanced for this historical fact. The first reason is simply that many positivist philosophers, especially Hume, were lucid and effective writers whose message could be readily grasped after a single reading of their works. The texts of Kant, and of his mainly Continental followers, are, by contrast, obscure and hard to understand.

The second reason for the long scientific neglect of Kant is more profound. After all, it does seem very strange that if, as Kant alleges, we bring such concepts as time, space, and causality to sensation a priori, these transcendental concepts happen to fit our world so well. Considering all the ill-conceived notions we might have had about the world prior to experience, it seems nothing short of miraculous that our innate concepts just happen to be those that fill the bill (*4*). Here the positivist view that all knowledge is derived from experience a posteriori seems much more reasonable. It turns out, however, that the way to resolve the dilemma posed by the Kantian a priori has been open since Charles Darwin put forward the theory of natural selection in the mid-19th century. Nevertheless, few scientists seem to have noticed this until Konrad Lorenz drew attention to it 30 years ago (*5*). Lorenz pointed out that the positivist argument that knowledge about the world can enter our mind only through experience is valid if we consider only the ontogenetic development of man, from fertilized egg to adult. But once we take into account also the phylogenetic development of the human brain through evolutionary history, it becomes clear that individuals can also know something of the world innately, prior to and independent of their own experience. After all, there is no biological reason why such knowledge cannot be passed on from generation to generation via the ensemble of genes that determines the structure and function of our nervous system. For that genetic ensemble came into being through the process of natural selection operating on our remote ancestors. According to Lorenz, "experience has as little to do with the matching of a priori ideas with reality as does the matching of the fin structure of a fish with the properties of water" (*5*). In other words, the Kantian notion of a priori knowledge is not implausible at all, but fully consonant with present mainstream evolutionary thought. The a priori concepts of time, space, and causality happen to suit the world because the hereditary determinants of our highest mental functions were selected for their evolutionary fitness, just as were the genes that give rise to innate behavioral acts, such as sucking the nipple of mother's breast, which require no learning by experience.

The importance of these Darwinian considerations transcends a mere biological underpinning of the Kantian epistemology. For the evolutionary origin of the brain explains not only why our innate concepts match the world but also why these concepts no longer work so well when we attempt to fathom the world in its deepest scientific aspects. This barrier to unlimited scientific progress posed by the a priori concepts which we necessarily bring to experience was a major philosophical concern of Niels Bohr (*6*). Bohr recognized the essentially semantic nature of science, pointing out

> . . . as the goal of science is to augment and order our experience, every analysis of the conditions of human knowledge must rest on considerations of the character and scope of our means of communication. Our basis [of communication] is, of course, the language developed for orientation in our surroundings and for the organization of human communities. However, the increase of experience has repeatedly raised questions as to the sufficiency of concepts and ideas incorporated in daily language.

The most basic of these concepts and ideas are precisely the Kantian a priori notions of time, space, and causality. The meaning of these terms is intuitively obvious and grasped automatically by every child in the course of its normal intellectual development, without the need to attend physics classes. Accordingly, the models that modern science offers as explanations of reality are pictorial representations built of these intuitive concepts. This procedure was eminently satisfactory as long as explanations were sought for phenomena that are commensurate with the events that are the subject of our everyday experience (give or take a few orders of magnitude). For it was precisely for its fitness to deal with everyday experience that our brain was selected in the evolutionary sequence that culminated in the appearance of *Homo sapiens*. But the situation began to change when, at the turn of this century, physics had progressed to a stage at which problems could be studied which involve either tiny subatomic or immense cosmic events on scales of time, space, and mass billions of times smaller or larger than our direct experience. Now, according to Bohr, "there arose difficulties of orienting ourselves in a domain of experience far from that to the description of which our means of expression are adapted." For it turned out that the description of phenomena in this domain in ordinary, everyday language leads to contradictions or mutually incompatible pictures of reality. In order to resolve these contradictions, time and space had to be denatured into generalized concepts whose meaning no longer matched that provided by intuition. Eventually it appeared also that the intuitive notion of causality is not a useful one for giving account of events at the atomic and subatomic level. All of these developments were the consequence of the discovery that the rational use of intuitive linguistic concepts to communicate experience actually embodies hitherto unnoticed presuppositions. And it is these presuppositions which lead to contradictions when the attempt is made to communicate events outside the experimental domain. Now, whereas the scope of science was enormously enlarged by recognizing the pitfalls of everyday language, this was achieved only at the price of denaturing the intuitive meaning of some of its basic concepts with which man starts out in his quest for understanding nature.

The Brain

In addition to explaining in evolutionary terms how the human brain and its epiphenomenon, the mind, can gain possession of a priori concepts that match the world, modern biology has also shown that the brain does appear to operate according to principles that correspond to the tenets of structuralism. By this statement I do not mean that the neurological correlates of any of the structuralist notions, particularly not of Freud's subconscious, or of Lévi-Strauss' ethnological universals, or of Chomsky's universal grammar, have actually been found. Such a claim would be nonsensical, inasmuch as it is not even known in which parts of the brain the corresponding processes occur. What I do mean, however, is that neurological studies have indicated that, in accord with the structuralist tenets, information about the world reaches the depths of the mind, not as raw data but as highly processed structures that are generated by a set of stepwise, preconscious informational transformations of

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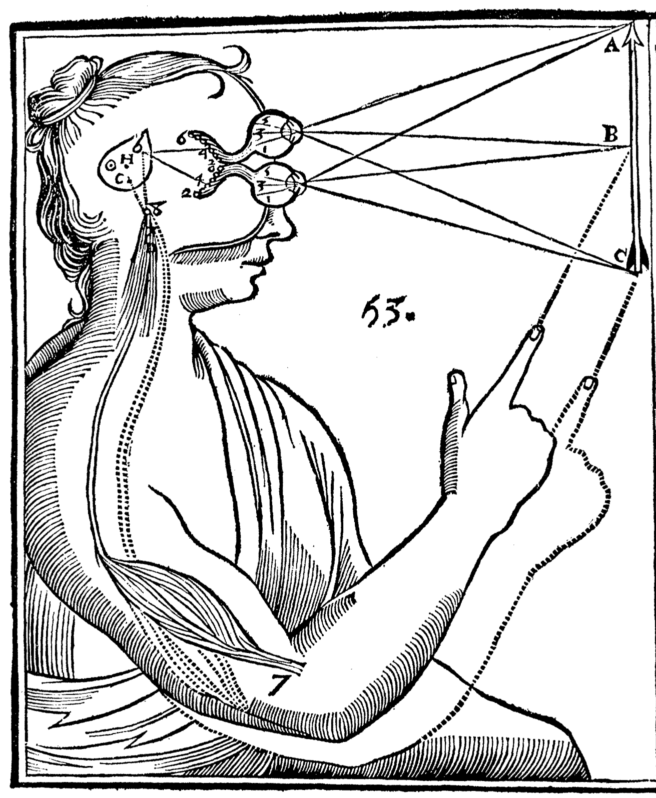

LXXVIII. Comment vne idée peut eſtre cõpoſée de pluſieurs;& d'où vient qu'alors il ne paroiſt qu'vn ſeul objet.

Et de plus, pour entendre icy par occaſion, comment, lors que les deux yeux de cette machine, & les organes de pluſieurs autres de ſes ſens ſont tournez vers vn meſme objet, il ne s'en forme pas pour cela pluſieurs idées dans ſon cerveau, mais vne ſeule, il faut penſer que c'eſt toujours des meſmes points de cette ſuperficie de la glande H que ſortent les Eſprits, qui tendant vers divers tuyaux peuvent tourner divers membres vers les meſmes objets: Comme icy que c'eſt du ſeul point b que ſortent les Eſprits, qui tendant vers les tuyaux 4, 4, & 8, tournent en meſme temps les deux yeux & le bras droit vers l'objet B.

Fig. 1. Descartes' theory of visual perception, as published posthumously in his Traité de l'Homme (1667). The pear-shaped cerebral structure labeled "H" is the pineal gland, thought by Descartes to be the gateway to the soul, where the percept is formed. Thus, according to this view, it is to the pineal gland that information from the input part projects and it is from the pineal gland that the commands to the effector part issue. [From the Kofoid collection of the Biology Library of the University of California, Berkeley. Courtesy of the University of California]

the sensory input. These neurological transformations proceed according to a program that preexists in the brain. The neurological findings thus lend biological support to the structuralist dogma that explanations of behavior must be formulated in terms of such deep programs and reveal the wrong-headedness of the positivist approach which rejects the postulation of covert internal programs as "mentalism."

One set of such neurological findings concerns the manner in which the nervous system of higher vertebrates, including man, converts the light rays entering the eyes into a visual percept. For the purpose of this discussion it is useful to recall that the nervous system is divisible into three parts: (i) an input or sensory part that informs the animal about its external and internal environment; (ii) an output, or effector, part that produces motion by commanding muscle contraction; and (iii) an internuncial part that connects the sensory and effector parts. The most elaborate portion of the internuncial part is the brain. The brain does much more than merely connect sensory and effector parts, however: It processes information. This processing consists in the main in making an abstraction of the vast amount of data continuously gathered by the sensory part. In order to abstract, the brain destroys selectively portions of the input data and thus transforms these data into manageable categories, or structures that are meaningful to the animal. It is on the basis of the perceived meaning that the internuncial part issues the relevant commands to the effector part which then results in an appropriate behavioral response.

The Visual Pathway

For vision, the input part of the nervous system is located in the retina at the back of the eye (Fig. 1). There a two-dimensional array of about a hundred million primary light receptor cells—the rods and the cones—converts the radiant energy of the image projected via the lens on the retina into a pattern of electrical signals, as does a television camera. Since the electrical response of each light receptor cell depends on the intensity of light that happens to fall on it, the overall activity pattern of the light receptor cell array represents the light intensity existing at a hundred million different points in the visual space. The retina contains not only the input part of the visual system, however, but also the first stages of the internuncial part. These first internuncial stages include another two-dimensional array of nerve cells, namely, the million or so ganglion cells. The ganglion cells receive the electrical signals generated by the hundred million light receptor cells and subject them to information processing. The result of this processing is that the activity pattern of the ganglion cells constitutes a more abstract representation of the visual space than the activity pattern of the light receptor cells. For instead of reporting the light intensity existing at a single point in the visual space, each ganglion cell signals the light-dark contrast which exists between the center and the edge of a circular receptive field in the visual space (7). Each receptive field consists of about a hundred contiguous points monitored by individual light receptor cells. The physiological mechanisms by means of which the input point-by-point light intensity information is abstracted to yield light contrast information are more or less understood. They can be epitomized simply by stating that the light receptor cells reporting from points at the center or the edge of the receptive field make respectively excitatory or inhibitory connections with their correspondent ganglion cell. Thus the ganglion cell is maximally excited if the field center receptors are struck by bright light while the field edge receptors are in the dark. In this way, the point-by-point fine-grained light intensity information is boiled down to a somewhat coarser field-by-field light contrast representation, thanks to an algebraic summation of the outputs of an interconnected ensemble of a hundred contiguous light receptor cells. As can be readily appreciated, such light contrast information is essential for the recognition of shapes and forms in space, which is what visual perception mainly amounts to.

For the next stage of processing the visual information leaves the retina via the nerve fibers of the ganglion cells. These fibers connect the eye with the brain, and after passing a way station in the midbrain the output signals of the ganglion cells reach the cerebral cortex at the lower back of the head. Here the signals converge on a set of cortical nerve cells. Study of the cortical nerve cells receiving the partially abstracted visual input has shown that each of them responds only to light rays reaching the eye from a limited set of contiguous points in the visual space. But the structure of the receptive fields of these cortical nerve cells is more complicated and their size is larger than that of the receptive fields of the retinal ganglion cells. Instead of representing the light-dark contrast existing between the center and the edge of circular receptive fields, the cortical nerve cells signal the contrast which exists along straight line edges whose length amounts to many diameters of the circular, ganglion cell receptive fields. A given cortical cell becomes active if a straight line edge of a particular orientation—horizontal, vertical, or oblique—formed by the border of contiguous areas of high and low light intensity is present in its receptive field (*8*). For instance, a vertical bar of light on a dark background in some part of the visual field may produce a vigorous response in a particular cortical nerve cell, and that response will cease if the bar is tilted away from the vertical or moved outside the receptive field. Actually, there exist two different kinds of such nerve cells in the cerebral cortex: simple cells and complex cells. The response of simple cells demands that the straight edge stimulus must not only have a given orientation but also a precise position in the receptive field. The stimulus requirements of complex cells are less demanding, however, in that their response is sustained upon parallel displacements (but not upon tilts) of the straight edge stimuli within the receptive field. Thus the process of abstraction of the visual input begun in the retina is carried to higher levels in the cerebral cortex. The simple cells, which evidently correspond to the first cortical abstraction stage, transform the data supplied by the retinal ganglion cells concerning the light-dark contrast within small circular receptive fields into information concerning the contrast present along sets of circular fields arranged in straight lines. And the complex cells carry out the next cortical abstraction stage. They transform the contrast data concerning particular straight line sets of circular receptive fields into information concerning the contrast present at parallel sets of straight lines.

The Grandmother Cell

It is not clear at present how far this process of cerebral abstraction by convergence of visual channels can be imagined to go. Nerve cells have already been found in the cerebral cortex which respond optimally to straight-line ends or corners in their receptive fields (9). Evidently, the output of these cells represents an even higher level of abstraction than the parallel straight lines of a given orientation to which the complex cells respond. But should one suppose that the cellular abstraction process goes so far that there exists for every meaningful structure of whose specific recognition a person is capable (for example, "my grandmother") at least one particular nerve cell in the brain that responds if and only if the light and dark pattern from which that structure is abstracted appears in its visual space (*10*)?

This could very well be the case for lower animals, with their limited behavioral repertoire. For instance, there is neurological evidence that the visual system of the frog abstracts its input data in such a way as to produce only two meaningful structures, "my prey" and "my predator," which, in turn, evoke either of two alternative motor outputs, attack or flight (*11*). But in the case of man, with his vast semantic capacities, this picture does not appear very plausible, despite the fact that the human brain has many more nerve cells than the frog's brain. Somehow, for man the notion of the single cerebral nerve cell as the ultimate element of meaning seems worse than a gross oversimplification; it seems qualitatively wrong. Yet, so far at least, it is the only neurologically coherent scheme that can be put forward. Admittedly, ever since the discipline of neurophysiology came into being more than a century ago, there have been adherents of a "holistic" theory of the brain. This theory envisions that specific functions of the brain, including perception, depend not on the activity of particular localized cells or centers but on general and widely distributed activity patterns. Such holistic theories, however, amount to little more than phenomenological recapitulations of neurological correlates of behavior or mental activity. They are not, therefore, explanatory in a scientific sense. This does not mean that the holistic approach to the brain is necessarily wrong; it merely means that it concedes at the outset that the brain cannot be explained.

The Self

We thus encounter the barrier to an ultimate scientific understanding of man which Descartes had recognized more than three centuries ago. Descartes had clearly outlined the nature of the problem posed by vision (Fig. 1), and the modern neurological findings mentioned in the preceding paragraphs represent latter-day triumphs of the Cartesian approach. At the same time, Descartes had realized that physiological studies really leave the central problem of visual perception untouched. For the percept is obviously a function of the *soul*, or in modern psychological parlance, of the *self*, whose nature Descartes thought to be inaccessible to scientific analysis. No matter how deeply we probe into the visual pathway, in the end we need to posit an "inner man" who transforms the visual image into a percept. And, as far as linguistics is concerned, the analysis of language appears to be heading for the same conceptual impasse as does the analysis of vision. I think it is significant that Chomsky, who views himself as carrying on the line of linguistic analysis begun by Descartes and his disciples (*12*), has encountered difficulty with the postulated semantic component. Thus far, it has not been possible to spell out how the semantic component manages to extract meaning from the informational content of the deep structure. It is over just the problem of meaning that disputes have arisen between Chomsky and some of his students, and it does not seem that any solution is at present in sight (*13*). The obstacle in the way of giving a satisfactory account of the semantic component appears to reside in defining explicitly the problem that is to be solved. That is to say, for man the concept of "meaning" can be fathomed only in relation to the self, which is both ultimate source and ultimate destination of semantic signals. But the concept of the self, the cornerstone of Freud's analytical psychology, cannot be given an explicit definition. Instead, the meaning of "self" is intuitively obvious. It is another Kantian transcendental concept, one which we bring a priori to man, just as we bring the concepts of space, time, and causality to nature. The concept of self can serve the student of man as long as he does not probe too deeply. However, when it comes to explaining the innermost workings of the mind—the deep structure of structuralism—then this attempt to increase the range of understanding raises, in Bohr's terms, "questions as to the sufficiency of concepts and ideas incorporated in daily language." Thus, the image of man as a Russian doll, with the outer body encasing an incorporeal inner man, is evidently a presupposition hidden in the rational linguistic use of the term "self," and the attempt to eliminate the inner man from the picture only denatures that intuitive concept beyond the point of psychological utility (*14*). From this ultimate insufficiency of the everyday concepts which our brain obliges us to use for science it does not, of course, follow that further study of the mind should cease, no more than it follows from it that one should stop further study of physics. But I think that it is important to give due recognition to this fundamental epistemological limitation to the human sciences, if only as a safeguard against the psychological or sociological prescriptions put forward by those who allege that they have already managed to gain a scientifically validated understanding of man (*15*).

References and Notes

1. An excellent overview of the structuralist movement can be obtained from H. Gardner, *The Quest for Mind* (Knopf, New York, 1973).
2. I am referring to Hume as a founder of positivism, even though the name of that philosophical view was invented much later by Auguste Comte, because he shaped 17th-century empiricism into the anti-metaphysical outlook that informed much of 19th- and 20-century science.
3. Unfortunately, calling Chomsky a "structuralist" is bound to raise confusion. Among students of linguistics, Chomsky is called a "generative grammarian," whereas not he but his positivistic predecessors, whose limited goals Chomsky has sought to transcend, are known as "structuralists." But in view of Chomsky's evident philosophical affinity to Freud, Lévi-Strauss, and other "structuralist" contributors to the human sciences, there seems to be no way to avoid this terminological confusion in a general discussion of his position.
4. Kant himself rejected the only resolution of this dilemma available at his time, namely, that it was God who put these concepts into man's mind.
5. K. Lorenz, *Bl. Dtsch. Philos.* **15**, 94 (1941).
6. N. Bohr, *Atomic Physics and Human Knowledge* (Science Editions, New York, 1961).
7. S. W. Kuffler, *J. Neurophysiol.* **16**, 37 (1953).
8. D. H. Hubel and T. N. Wiesel, *J. Physiol. (Lond.)* **160**, 106 (1962).
9. ———, *J. Neurophysiol.* **28**, 229 (1965).
10. A fuller discussion of the crucial importance of this question for an eventual neurological account of perception is given H. B. Barlow, *Perception* **1**, 371 (1972).
11. J. Y. Lettvin, H. R. Maturana, W. S. McCulloch, W. H. Pitts, *Proc. Inst. Radio Eng.* **47**, 1940 (1959).
12. N. Chomsky, *Language and Mind* (Harcourt, Brace & World, New York, 1968).
13. J. Searle, *New York Rev.* 29 June (1972), p. 16.
14. Thus I reject S. Toulmin's claim [in *The Neurosciences*, G. C. Quarton, T. Melnechuck, F. O. Schmidt, Eds. (Rockefeller Univ. Press, New York, 1967), p. 822] that the picture of the inner man is merely a legacy of the applications of 17th-century physics to the study of man and that the need for the concept vanishes within the frame of reference of 20th-century physics. Referring to an entirely different nonscientific tradition, we may note that the *satori* of Zen Buddhism demands purging the mind of its innate self concept and that the deep insights into man gained thereby cannot consequently be communicated by explicit verbal discourse.
15. After this article had gone to press I came upon *Seelenglaube und Psychologie* (Deuticke, Leipzig, 1930) by Freud's disciple and critic Otto Rank. Using many of the same arguments that I put forward here, including the epistemological parallels between 20th-century physics and psychology, Rank concluded that the unavoidable concept of the soul limits the eventual scientific understanding of man. I am indebted to A. Wheelis for calling my attention to Rank's book.