Committee I
The Unity of the Sciences

#26

Draft-For Conference
Distribution Only

SPONTANEOUSLY ORDERED COMPLEX PHENOMENA AND THE UNITY OF THE MORAL SCIENCES

by

Walter B. Weimer
Professor of Psychology
Pennsylvania State University
University Park, PA, USA

The Twelfth International Conference on the Unity of the Sciences
Chicago, Illinois November 24-27, 1983

#26

Spontaneously Ordered Complex Phenomena and the Unity of the Moral Sciences

Walter B. Weimer

The Pennsylvania State University

The more we move into the realm of the very complex, the more our knowledge is likely to be of the principle only, of the significant outline rather than of the detail.... The fact is that in studies of complex phenomena the general patterns are all that is characteristic of those persistent wholes which are the main object of our interest, because a number of enduring structures have this general pattern in common and nothing else.

F. A. Hayek

Paper prepared for Committee I of the Twelfth International Conference on the Unity of the Sciences, Chicago, November 24-27, 1983.

This essay overviews common themes in our understanding of areas of inquiry that were once called the moral sciences (in opposition to the natural sciences). Its aim is to show the unity of method and principles of theory construction that characterize successful moral science inquiry, and the extent to which such understanding is fundamentally different from that found in most natural science inquiry. The primary distinction that must be made at the outset is between relatively "simple" and relatively "complex" phenomena. The only tenable unity of science is in terms of unity of methods and aims, and while the Popperian metatheoretical account of "conjectures held in check by refutations" and "the quest for truth" provides an initial characterization of method and aim, the realization of both is quite different in domains of complex phenomena than it is in the relatively simple natural science situation. Thus my first task is to characterize spontaneously arisen complex phenomena, and to show that the informative distinction is one between simple and complex rather than physical versus social, hard versus soft, *Naturwissenschaft* versus *Geisteswissenschaft*, and other familiar contrasts.

With the characteristics of spontaneous complex orders outlined I shall proceed to my central thesis--that all successful theorizing in domains of essential complexity has made use of a context of constraint that utilizes a fairly small number of abstract regulative principles to capture the regularity of what are in essence dynamic equilibrating systems that exist and evolve only as a delicate balance of essential tensions. The evolution of all spontaneous orders appears to be an essential tension between three sets of principles that regulate change. The first principle that reappears in all such orders is one of creativity or productivity. All these systems exhibit fundamental novelty, change (at the level of particulars) that cannot be predicted in advance. The second principle is that of rhythm, and the progressive differentiation of rhythm. Evolutionary differentiation is rate dependent instead of rate independent. The third principle is that development tends towards opposites, or the principle of regulation by opponent processes. There is much that is correct in the ancient theme of dialectical development, and it can be given a modern interpretation that repudiates the nonsense spouted by romantic idealists such as Hegel and later scientistic "dialectical materialists." The interaction of these three principles creates an essential tension, a context of constraint, between the previous form of organization, the ongoing state, and changes that may occur. This essential tension between tradition and innovation, stability and change, is an inherent aspect of the spontaneously evolving complex orders that populate the moral sciences. The unity of the sciences of complex phenomena is found in the common methods they have developed to deal with the essential tension of these interacting principles.

Epistemology and the methodology of scientific research, the theory of knowledge and theory of science as the search for knowledge, are equally part of the moral sciences dealing with spontaneously arisen complex phenomena--the organization of the individual acquiring knowledge and the social organization of research. An inherent danger in all the moral sciences is the scientistic attempt to model complex phenomena analogously to paradigms of artificial and restricted--simple--phenomena found in classical physical science and classical mathematics. In its traditional guise as the prejudicial attempt to fit all science into the model of simple phenomena scientism is well known and thoroughly repudiated by many contemporary philosophers. But there is another attitude, common since the dawn of reflective thought, that is sufficiently pervasive to be a metatheory or world view that encompasses the Procrustean hubris of scientism and much more. I have dubbed that point of view, following F. A. Hayek, rationalist constructivism: the tendency to limit rationality and desirability of social and institutional phenomena to explicit control by conscious awareness, the desire to remodel all human activity (especially science and social activity) according to plans specified "rationally" in advance, and acceptance of the Cartesian view that alone among the constituents of the natural order the mind of mankind can step outside that order to judge and correct it.

Even rudimentary understanding of the evolution of complexity annihilates the conceptual arguments of the rationalist constructivist world view, and the third theme of this essay is to expose constructivism's theoretical inadequacy and its disastrously retarding effect upon the spontaneous orders of mankind and society when it controls technology and practical affairs. Initially this will be a running argument (chiefly in footnote material) aimed against scientism and interventionist policies in the economic and political orders. But since epistemology and methodology deal with complex spontaneous orders a parallel argument against constructivist thought is also in order. Thus I shall conclude with a discussion of the implications of complex orders for explicit and prescriptive methodological accounts, in order to delimit how a nonjustificational fallibilist philosophy must incorporate the repudiation of rationalist constructivism.

I. Spontaneous Complex Orders

We are dealing here with parts of logics with which we have practically no past experience. The order of complexity is out of all proportion to anything we have ever known. We have no right to assume that the logical notations and procedures used in the past are suited to this part of the subject.

John von Neumann

The span of control of a spontaneous system, divided by the number of its members, increased proportionately to this number, while the span of control of a corporate system, divided by the number of its ultimate subordinates, is practically unaffected by an increase in the size of the system.

Michael Polanyi

In Psychology we find that only those mental phenomena which are directly accessible to physical influences can be made the subject matter of experiment. We cannot experiment on the mind itself, but only upon its outworks, the organs of senses and movement which are functionally related to mental processes.

Wilhelm Wundt

By spontaneously organized complex orders I mean those biological, social and (only recently studied) physical phenomena that evolve without conscious or explicit planning (or externally imposed controls) according to internal regulative principles. They are characterized by decentralized "coalitional" control, unpredictability of particulars, and immense complexity compared to simple systems. While self producing, they also exhibit evolutionary novelty or creativity.[1] They are understandable only in terms of what Hayek (1967) called explanation of the principle rather than the particular. Their principles of regulation are rules of interactive constraint rather than deterministic laws as philosophers usually use the term. If "control" is identified with determinism and prediction of particulars then no spontaneous complex order is controlled or "lawful." Spontaneous orders are constrained by abstract rules, not controlled by deterministic laws. Constrained orders are determinate--regulated by general principles of organization--but not deterministic and/or predictable. They are, as Popper (1972, 1982) and Bronowski (1978) have emphasized, cloud like systems that have the power to look like clockwork mechanisms.

<u>A precise but unspecifiable definition of complexity</u>. Let us begin to see what is involved by unpacking "complex" as opposed to "simple" systems. The complexity of spontaneous orders results in a <u>qualitatively</u> different class of problems in the moral sciences from those encountered in the "simple" natural sciences. Qualitative differences emerge from quantitative changes in the subject matter. They emerge at a precise but unspecifiable point: where the least complex rigorous model of a

phenomenon is as complex as the phenomenon itself. In the realm of (relatively) simple phenomena we can build (physically or intellectually) a model of how something works that is less complex than the thing itself: the model simplifies and economizes to enable us to grasp the phenomenon intellectually. For high complexity the reverse occurs: models are either more complex than the phenomenon under study, or equally complex, and thus do not enable us to simplify in the attempt to understand. As Hayek (1967) has emphasized, for high complexity we are limited to understanding the abstract regulative principles of the order rather than ever being able to model its particulars (either deterministically or deductively).

This way of specifying complexity can be called von Neumann's conjecture, and it stems from his pioneering work in the theory of self-reproducing automata and the organization of the nervous system (1951, 1966). As von Neumann (1966) put it,

> It is characteristic of objects of low complexity that it is easier to talk about the object than produce it and easier to predict its properties than to build it. But in the complicated parts of formal logic it is always one order of magnitude harder to tell what an object can do than to produce the object. (p. 51)

The problem of understanding the central nervous system (CNS) had led von Neumann to this conjecture, and earlier (1951) he put this point in terms of a discussion of modelling the visual system:

> It is not at all certain that in this domain a real object might not constitute the simplest description of itself, that is, any attempt to describe it by the usual literary or formal-logical method may lead to something less manageable and more involved....

> It is, therefore, not at all unlikely that it is futile to look for a precise logical concept, that is, for a precise verbal description, of "visual analogy." It is possible that the connection pattern of the visual brain itself is the simplest logical expression or definition of the principle. (p. 24)

This puts the program of explanation by covering laws of particulars in complex domains in the realm of utopian fantasy. The pattern of explanation that was so helpful for classical physics is not an adequate model for all of science, and its scientistic application to the complex moral sciences can only lead to disaster.

Limits of explanation: complexity and explanation of the principle. Von Neumann's conjecture leads to an abstract constraint on systems of explanation: It is beyond the capacity of systems to explain or model phenomena that are more complex than the systems themselves. An obvious limitation is reached in self-explanation: A system can only be itself, it can never model or explain itself. An explaining system must be more complexly organized than the thing it models. Thus no system, such as the human brain, could ever fully explain its own operations (as was first noted by Hayek, 1952). This purely logical point relates directly to the concept of explanation of the principle. It follows that all our understanding can hope to achieve in domains of organized complexity is explanation of the abstract principles according to which the system is constrained to function. We will never be able to model such systems completely, nor will we be able to corroborate the adequacy of our models in all particulars. Instead our knowledge of a model's adequacy will be negatively determined by falsification, in which case we learn only that it is incorrect, and a good model is one that has, as Popper (1959) suggested, thus far survived sincere attempts to refute it.

Thus explanation points beyond itself to the structure of rules which determines explanation but cannot be explained by it at the same time. This limitation must not be confused with the claim that there are

> Particular rules which no such system could ever state. All the former contention means is that there will always be some rules governing a mind which that mind in its then prevailing state cannot communicate, and that, if it ever were to acquire the capacity of communicating these rules, this would presuppose that it had acquired further higher rules which make the communication of the former possible but which themselves will still be incommunicable. (Hayek, 1967, p. 62)

Precisely because we cannot model particulars exhaustively in complex phenomena we must concentrate upon that which is attainable: explanation of abstract principles capable of generating infinite particularity.

But what sorts of understanding does explanation of the principle provide? Hayek (ibid) answers this way:

> We know that, <u>if</u> the mechanism is the same, the observed structures must be capable of showing some kinds of action and unable to show others; and if, and so long as, the observed phenomena keep within the range of possibilities indicated as possible, that is so long as our expectations derived from the model are not contradicted, there is good reason to regard the model as exhibiting the principle at work in the more complex phenomenon [under study].... Our

> conclusions and predictions will also refer only to some properties of the resulting phenomenon, in other words, to a kind of phenomenon rather than to a particular event. (p. 13)

We can conjecture about the abstract principles underlying complex phenomena and test them against particulars, but our knowledge will be limited to classes of phenomena compatible with given particulars. In such situations explanation is a specification of the context of constraint, not the deduction of particulars.

In sum, the unity of the moral sciences is found in the common methods they have evolved for specifying the contexts of constraint that are their complex orders. Explanation is a matter of the specification of the context of constraint, not deduction of particulars. There is a unity of explanatory pattern in the moral sciences, but not the one proposed by positivism.

Rules versus laws. Thus the character of the sciences of the complex will be quite different from that of the sciences of the relatively simple. They will be much more metaphysical (indispensibly involving metaphysical research programs, if you will) and less directly testable, and incapable of prediction and control except in artificially restricted circumstances. Thus while empirical, they will not necessarily be experimental. Nor will they disclose "laws of nature" as that phrase is interpreted in classical "simple" science. Deterministic relationships such as Newton's $F = m\,a$ will not be characteristic of the moral sciences. All we can expect are pattern predictions that result from postulating abstract rules underlying surface particulars. Prediction and control, although characteristic of low complexity accounts, will be conspicuously absent. When they do occur it will be as artificial limiting cases in which complexity is constrained by experimental technique.

To understand a complex order in terms of principles of regulation according to which it changes is not the same thing as to understand a simple situation in terms of (quantifiably determinate) laws; nor is it a counsel of despair "second best" approach. Due to the limits of human information processing we could never comprehend the welter of particulars in any way except in terms of their relationship to abstract rules. Prediction of particulars, their exact quantification, and deterministic laws are utterly meaningless concepts except in realms of low complexity.[2]

Not all "research" is experimental manipulation. If one were to ask practitioners of the "soft" sciences "what do you do in your research?" the result, especially in fields influenced by scientistic emulation of "hard" science, would likely be a statement of laboratory isolation of manipulable "variables" in a controlled situation with results statistically analyzed according to accepted designs. No one can doubt that "simple" sciences have been successful in employing such experimentation, nor that empirical laws result from our ability to experiment, which is essentially the ability to simplify and control a situation to the extent that it can be repeated (or systematically varied).

In complex domains, however, research is more demonstration than experimentation, qualitative rather than quantitative. Instead of the experimental isolation of relevant variables empirical research in complex social phenomena consists in the construction of (or stumbling upon) situations in which we demonstrate to ourselves that we can produce patterns of "facts" of which we are already well aware. Our demonstrations test our theoretical models only in the sense already noted--neither by justificationist confirmation nor refutation, but rather only by comparing them for consistency with our analogical knowledge of social phenomena. A similar situation holds for biological and physiological research that involves essential complexity (not all life sciences research, of course, is concerned with complex orders, and thus some is legitimately experimental): such research is empirical demonstration rather than experimental manipulation.

While the position I have summarized is familiar as the Austrian approach to methodology (as represented in the work of Mises, 1960, Hayek, 1948, and others--see Gray, 1982) in economics, it is less often recognized to be the position independently arrived at by the classic fathers of psychology, Wundt and Brentano. Both theorists argued that in the study of complexity, the higher mental processes, experimentation is impossible. Since Brentano defined such study as psychology his classic Psychology from an empirical standpoint (1874/1973) argued that psychology should be empirical demonstration, not experimentation. Wundt, in contrast, considered cognition part of the Volkerpsychologie, and restricted "psychology" to the study of lower processes by experimental introspection. The message of both theorists was lost in the rise of behaviorism, and has only recently been reintroduced to cognitive psychology (chiefly by A. L. Blumenthal, 1970, 1977; see also Weimer, 1974, 1982b). This point was forcibly reemphasized by the rise of psycholinguistics influenced by Chomsky's linguistics, when it became obvious that one cannot understand language by attempting to "sharpen the blurred edges" in the statistical picture of the surface form of language. We understand creativity in cognition only by coming to grips with the deep structural rules of determination that can be manifested in indefinite surface particularity.[3]

The Central Nervous System as a Complex Order

We can elaborate upon the previous discussion and also explain further concepts essential to complex orders by looking at a concrete example: the human CNS. Our understanding of brain functioning and neural organization increasingly pictures the evolution of immense complexity. Previous research had attempted to model the CNS by studying "simple" organisms and behaviors in constrained situations in order to get basic building blocks for a theory of human behavior as an additive result. But a different approach is implicit in the chastening remarks of the ex-behaviorist Karl Lashley (1951):

> I am coming more and more to the conviction that the rudiments of every human behavioral mechanism will be found far down in the evolutionary scale and also represented even in primitive activities of the nervous system. If there exist, in human cerebral action, processes which seem fundamentally different or inexplicable in terms of our present construct of the elementary physiology of integration, then it is probable that that construct is incomplete or mistaken, even for the levels of behavior to which it is applied (pp. 134-135).

Let us pursue that thought into the CNS as an instrument of organized complexity.

The control structure of the mind. The definition of (high) complexity provided by von Neumann arose primarily in discussion of the nature and capacity of the (human) central nervous system. It should be obvious that although it is anatomically isolated within an individual's body the CNS is as highly complex as any social cosmos, and in terms of numbers of constituents (about 5×10^{11} neurons in the human neocortex) the brain constitutes a far larger aggregation than the present world population. Thus it is worth looking at the possible mathematical systems and control relations that have been proposed as models for its operation. We find, when doing so, that it is only in the last forty or so years that the necessary conceptual tools for such an analysis have been available. With perfect hindsight we can see that traditional conceptions have been ludiciously inadequate.

As a result of Chomsky's (1957, 1965) analysis in linguistics and the study of Post (1943) languages it has become clear that associationism as a mechanism of the mind is equivalent to a linear or chaining control model that has the generative capability of a finite state automaton. Since language requires at least transformational complexity in its generation, both the British associationist account and all variants of behaviorism are logically impossibly inadequate models of mind (since language is only one higher mental process). The next step up in control complexity is a hierarchical model and theorists have proposed such an account as a replacement for associationism since World War II (see Lashley, 1951; Hayek, 1952; Bertalanffy, 1962). At about the same time Polanyi (1951) emphasized the difference between "polycentric" orders such as the spontaneous market and "monocentric" orders such as corporate "control" of a company. Unfortunately psychologists were unaware of Polanyi's economically based discussions, for they show quite clearly that hierarchical orders, which are monocentric, cannot explain a polycentric cosmos.[4] Now the question arises: Is the CNS functionally equivalent to a cosmos? Why is it not monocentric like a taxis, a giant hierarchy of hierarchical control structures?

One way to answer the question is to consider the effect of disruption on possible control models. In a chaining model, breaking a link terminates ongoing performance at that point: no control is passed over the disruption. Lashley's experimental results with cerebral lesions in rats (1929) killed chaining models before the great age of learning theory, but behaviorists, unaware of physiology as well as the nature of associationism, went on with such models with gay abandon until the 1960's. A hierarchical structure is indefinitely more powerful--since the controlling relations are from top to bottom rather than between terminal elements, even the removal (perhaps by cortical lesion) of a higher node does not totally disrupt behavior. Lashley's results supported that conclusion: The decrement in trained performance in various tasks following surgical disruption was always partial, unless virtually all the cortex was obliterated. But a hierarchy, even if it has other hierarchies under it, is still a centralized control structure with one node functioning as chief executive officer (the homunculus in the head). Do we really have one "upstairs" in our heads? We can get rid of this piece of internal rationalist anthropomorphism very easily, despite the fact that our waking consciousness is quite pleased to be regarded as a single self.

Two lines of "evidence" are relevant (see Weimer, 1977). First is our intuitive familiarity with the tacit dimension of skilled performance. Not only can we recall a difficult problem (in say, algebraic structure theory), but we can do so while carrying on a conversation (not necessarily related to that topic) as part of our tennis game, or while driving with a friend (during which time we are also breathing, digesting our food, and a myriad other bodily functions are being carried on). They all mutually interact, to be sure, but they are far too independent to be hierarchically related. One can stop breathing (holding one's breath) without disrupting any of the other activities (except perhaps vocal activity--but one could write the problem down). There is a constant interaction (better: mutual coordination) between highly complicated activities that individually look like they are hierarchical control functions.

A second line of evidence is constituted by research stemming from Roger Sperry's (1969, 1976) pioneering study of corpus callosum sectioning. Here the data indicate a plurality of "selves" that are largely independent of each other when commisurotomy removes the main linkage between the hemispheres. Such "divided" consciousness or "split brain" results support the ancient Yoga tradition that asserts that consciousness and the other higher mental processes are but tools used by an "I" that cannot be identified with any of them. Additional evidence for independence greater than that permitted by hierarchical control is provided by work on traumatic cerebral insult, such as the patients (largely war wounded) studied by H. L. Teuber (1960), and the effects of direct cortical brain stimulation pioneered by Wilder Penfield (Penfield & Roberts, 1959; Penfield, 1975).

Indeed, one can look to more "basic" biological processes such as the growth transformation of the face and head (see Enlow, 1968) and see the same problem: There is no single locus of control determining the remodelling of the face as the individual ages. What we find is a mutual coordination of diverse factors that constrain one another, but no determinism and no ultimate control center.

Such examples exemplify what Polanyi (1951) called polycentric orders, and what von Foerster (1962) and Shaw (Shaw & McIntyre, 1974) have termed coalitional control. The person (CNS) as a whole seems to be a coalition of (perhaps) hierarchical structures, somehow allied together but with no single locus in ultimate control, even when observable behavior appears to be exclusively occupied with one task, or when conscious awareness says "I am in charge." There is cooperation and mutual coordination, a context of interacting constraint, but no single control center. Decentralization of control is one of the definitive properties of coalitions. A second is the lack of a determinantly specifiable boundary between the coordinated systems. Clearly perception is not memory or locomotion, but one cannot sharply separate any of the three. Thus the boundaries of a coalition both as a whole and within itself are intrinsically "fuzzy." A third crucial property is that coalitional structures are superadditive. As the Gestalt phrase goes, the whole is more than the additive sum of its parts. What the coalition can "do" is vastly greater than any of its components, even when the latter are individually summed up.

Insert Figure 1 about here

Some graphic illustrations may help clarify what is involved. Compare the control relationships represented by a chaining model and a hierarchy in Figure 1. If one were to disrupt the chain at the occurrance of d, for example, the chain is broken and nothing else can occur.

If one were to remove the node labelled D, it would remove g and h, but the remainder of the sequence would be intact. Now consider the circular structure Polanyi used to represent a polycentric order in Figure 2. The complexity of relatedness in this arrangement increases as the number of nodes is increased, and the consequence of disruption at any location is minimal in comparison with the hierarchical model.

Insert Figure 2 about here

A more adequate representation of a cosmos such as the brain would require a three dimensional sphere with control connections going through the interior. By the time one considers the possible interconnections of 5×10^{11} neurons the sphere is in effect solid: anything is connected with everything, and anything can "control" anything else. One can also "see," by looking at Figure 2, why coalitions have fuzzy boundaries and superadditive capacity compared to hierarchies. Perhaps at this point one can better appreciate von Neumann's remark that "the order of complexity is out of all proportion to anything we have every known" (1951, p. 24).

Recent research on the structural and functional organization of the cortex has made it obvious that the brain functions as a distributed information processing system that is effectively coalitional. Mountcastle (1978) noted three findings that put brain functioning in a new light. First, the neocortex is constructed by a process of cloning identical multicellular units or modules. The modular unit of the neocortex is a vertically organized or columnar group whose functioning appears to be similar throughout (recall Lashley's "evolutionary scale" remark). Second, the extrinsic connectivity between larger anatomical entities in the brain is vastly greater than earlier research had recognized. Third, the separate modules of large entities are fractionated into subsets, linked by a particular pattern of connections to similar modules in other entities. The effect of these three findings is to corroborate a picture of distributed systems linked in echeloned serial and parallel connections. As Mountcastle (1978) noted, "Information flow through such a system may follow a number of different pathways, and the dominance of one path or another is a dynamic and changing property of the system" (p. 40).

This leads to coalitional control that is distributed throughout the functioning system:

> A distributed system displays a redundancy of potential loci of command, and the command function may from time to time reside in different loci of the system, in particular in that part possessing the most urgent and necessary information.
>
> An important feature of such distributed systems, particularly those central to primary sensory and motor systems, is that the complex function controlled or executed by the system is not localized in any one of its parts. The function is a property of the dynamic activity within the system: it resides in the system as such. Part functions, or simple aspects of system function, may be executed by local operations in restricted parts of such a system (p. 40).

This capacity, underlying the tacit dimension of the CNS, is what separates man from a machine, <u>including</u> conceptual devices such as Turing machines, so long as they are assumed to compute in discrete steps. Jacob Bronowski (1978) put this succinctly in his Silliman lectures in 1967:

> What is it that the brain can do? Where does the brain fail to be bound by these uncertainties and paradoxes [due to Godel, Turing, and Tarski]? . . . The wholeness of the human being must not be violated by separating the brain from the body. . . . There is no little observer who looks at the camera obscura inside your head. This notion arises from problems of consciousness and self-consciousness, divisions between the world and ourselves, and essentially it arises from the whole Cartesian dualism between the mind and the body. What is wrong with this? What is wrong is that if you think of the brain as receiving the information, processing it, and then giving an instruction to the muscle, you have already falsified the whole procedure. There is no nerve without the muscle and no muscle without the nerve in the total animal (p. 99).

As soon as one separates the brain from the muscle, to ask what order it is going to give, we falsify the nature of the brain. Sharply separating mind and body, or perceiving and acting (as information processing approaches are want to do) is an error analogous to putting the otherwise spontaneous individual in a Skinner box--it treats a cosmos as a taxis.[5]

Of Clocks and Clouds. The metaphysical thesis of strict determinism says that everything in the universe is a clockwork mechanism--that is, regular, orderly, and to omniscient intelligence highly predictable. As what Popper would term a metaphysical research program it directs us to interpret everything as a clock, and to postulate that prima facie exceptions, such as clouds, should be analyzed into smaller or more abstract deterministic clockworks. Since his Comton lecture in 1965, Popper (1972) has opposed physical determinism--the thesis that all clouds are clocks--by arguing that all clocks are clouds. He argues for physical indeterminism and against closed or boxed conceptions of physical theory and the behavior of man (see also Popper, 1982).

But sheer indeterminism is not all that Popper argued for: "We have to be indeterminists, to be sure; but we also must try to understand how men, and perhaps animals, can be 'influenced' or 'controlled' by such things as aims, or purpose, or rules, or agreements" (p. 230). Popper, following Comton, wants a form of plastic control that is not 'cast iron' or rigid. His problem is to reconcile freedom with some form of control. Rejecting the possible "quantum leap" effects upon our otherwise rigid nervous systems as inadequate to account for the open system of man he proposes an evolutionary account based upon trial and error: an exosomatic evolution in which humans are plastically controlled by the argumentative and critical function of language. Thus we are not forced to submit to the control of our theories, but can critically assess them, and if necessary reject them. Generalized to all species, his thesis is that "Each organism can be regarded as a hierarchical system of plastic controls--as a system of clouds controlled by clouds. The controlled subsystems make trial-and-error movements which are partly suppressed and partly restrained by the controlling system" (p. 245). Popper locates freedom and rationality in the same process--the critical process. Consciously adopting the critical attitude is "the highest form so far of the rational attitude, or of rationality" (p. 247).

Without here discussing this latter identification of freedom and rationality with conscious criticism, we must note that there is an affinity between the conception of the active brain, as a coalitional structure, and the cloud. As Edelman (1978) noted, the model of the CNS as coalitional and coordinate is not deterministic. As he put it (in slightly different terminology): "It would be a mistake to conclude. . .that a system of group-degenerate selection with re-entry of signals operates in clockwork fashion. . . . Selection can occur from cell groups participating in these states without 'telling molecules what to do'" (p. 86). The lack of determinate predictability of our behavior--especially obvious in our creative use of language--is quite cloud like as opposed to clock like. As Bronowski (1978) said, speaking of word associations, "These responses must have this statistical character: You feed in a perfectly definite piece of information, you get out a perfectly definite answer, but what goes on inside is not at all a computer-like process. It must be much more like the process which we imagine to go on in a cloud of gas" (p. 105). Rule governed creativity as instantiated in a computer or an explicit grammar is one thing, but the way in which the brain operates may well be another.

Consider some famous, if cryptic, remarks of von Neumann in this context (1958):

> What matters are not the precise positions of definite markers, digits, but the statistical characteristics of their occurrence, i.e. frequencies of periodic or nearly periodic pulse-trains, etc.
>
> Thus the nervous system appears to be using a radically different system of notation from the ones we are familiar with in ordinary arithmetics and mathematics: instead of the precise

> systems of markers where the position--and presence or absence--of every marker counts decisively in determining the meaning of the message, we have here a system of notations in which the meaning is conveyed by the statistical properties of the message (p. 79).

The statistical as opposed to mathematical character of the nervous system can be understood more clearly with the realization that the digital, all or none spike potential of neural firing is only one type of event in the functioning nervous system. In addition there is the fuzzy, or cloud like, graded potential activity emphasized by Pribram (1971b) as a mechanism for wave front interference phenomena. The holographic model of neural functioning that Pribram postulates takes advantage of the clouds of pre- and post-synaptic dendritic slow potentials to provide a plausible interpretation of the distributed information processing and retrieval characteristics of the CNS, particularly in perceptual "imaging."

But while cloud like, the dendritic slow potential activity is still structured. It is part of the language of the brain. Von Neumann warned us that the language used by the brain would be quite different from what would program a computer (1958):

> Logics and mathematics in the central nervous system, when viewed as languages, must structurally be essentially different from those languages to which our common experience refers. . . . Thus the outward forms of our mathematics are not absolutely relevant from the point of view of evaluating what the mathematical or logical language truly used by the central nervous system is (p. 82).

What Pribram (1971b, 1977) proposes is that the CNS uses both a digital code and an analog one. Thus instead of leaving us hanging in indeterministic air as Popper does, Pribram proposes (as does Edelman, 1978) that the two process model provides exactly the sort of plastic control that evolution requires, but on an abstract (indeterminate) rather than indeterministic basis at the level of neural functioning:

> The consequence for this view is a reevaluation of what we mean by probabilistic. Until now, the image, the model of statistics, has been indeterminacy. If the above line of reasoning is correct, an alternate view would hold that a random distribution is based upon holographic principles and is therefore determined. The uncertainty of occurrance of events is only superficial and is the result of holographic "blurring" which reflects underlying symmetries. . .and not just haphazard occurrences (Pribram, 1977, p. 98).

Pribram's account is partially based upon and congruent with David Bohm's (1978) attempts to penetrate beyond quantum theory with a "hidden variable" account that would, effectively, reinstate the physical deterministic world hypothesis that all clouds are actually clock like at a smaller level of analysis. Regardless of whether the universe is ultimately one way or the other, we must note that determinate orders function at particularly levels of analysis, and what appears to be deterministic clock work at our level is usually an indeterministic cloud at another level. It is in the regulation of complexity that we see most clearly the essential tension between clocks and clouds, (level) determinism and (level) indeterminism, and the emergence of determinate order as an outcome of the interaction of different levels. Spontaneously evolved complex orders will have both clock and cloud like aspects, and one must beware of the reductionistic tendency to dismiss one in favor of the other. What we must not do is identify the CNS (or other complex orders such as the market order) with any extant rigorous model of control (such as any machine).

Human beings, like market orders, are not machines. We have no reason to disagree with these remarks of Bronowski (1978), which state the primacy of abstract theory over particulars, the importance of trial and error, and above all an optimism that is part of any genuine humanism.

> As soon as the system runs into a fault, into an inconsistency, the human mind, unlike the machine, has the ability to throw the whole thing away and start building up a new. . .system. . . .
>
> I do not believe that human beings are consistent either, but I think that they have a strategy for coping with inconsistencies which they meet. Let me invent a phrase on the spur of the moment. What human beings have that machines do not have is superb optimism. You know, the thing breaks down, and by Jove, next day they are at it again (p. 86).

Consequences for Theory Construction

The moral for theory construction in the realms of organized complexity should be clear. Research that stems from the organization approach of the scientistic constructivist will, because of the ability of spontaneous orders to mimic, or perform like, a taxis, initially appear to confirm a simple picture of the cosmos in question. It will only be apparent later, as more and more disparity in results is attributed to "lack of control" or "environmental complexity," that things might not be so simple as was once thought.[6] Then it will be necessary to reassess two things: First, the nature of explanation in science, especially in domains of essential complexity; and second, the value of putting the open systems of mankind and society into a closed box. It will be apparent that the goals of explanatory theory will be concerned with principles rather than experimental regularities, and that the study of man made boxes will yield results that are functionally ambiguous. In the social realm especially it will be clearer why we should take the research strategy of Wundt and Brentano (and Menger, Mises, and Hayek), which is, after all, only an extension of the views of Kant and Hume, more seriously than that of Watson and Skinner (or Keynes, Samuelson, and Simon).

References

Alchain, A. A. _Economic forces at work_. Indianapolis: Bobbs-Merrill, 1977.

Allen, P. M. The evolutionary paradigm of dissipative structures. In E. R. Jantsch (Ed.), _Toward a unifying paradigm of physical, biological, and sociocultural evolution_. Boulder, Colo.: Westview, 1981.

Allen, P. M., & Sanglier, M. Order by fluctuation and the urban system. In M. Zeleny (Ed.), _Autopoesis, dissipative structures, and spontaneous social orders_. Boulder, Colo.: Westview, 1980.

Anderson, R. M., Jr. Wholistic and particulate approaches in neuropsychology. In W. B. Weimer & D. S. Palermo (Eds.), _Cognition and the symbolic processes_. Hillsdale, N.J.: Lawrence Erlbaum, 1974.

Barry, N. _Hayek's social and economic philosophy_. London: Macmillan, 1979.

Barry, N. The tradition of spontaneous order. _Literature of Liberty_, 1982, _V_(2), 7-58.

Bartley, W. W., III. _The retreat to commitment_. New York: Knopf, 1962.

Bartley, W. W., III. The philosophy of Karl Popper: Part I: Biology and evolutionary epistemology. _Philosophia_, 1976, _6_, 463-494.

Bartley, W. W., III. The philosophy of Karl Popper: Part III: Rationality, criticism, and logic. _Philosophia_, 1982, _11_, 121-221.

Bertalanffy, L. von. _General system theory_. New York: George Braziller, 1968.

Blumenthal, A. L. _Language and psychology_. New York: Wiley, 1970.

Blumenthal, A. L. _The process of cognition_. Englewood Cliffs, N.J.: Prentice-Hall, 1977.

Bohm, D. Wholeness and the implicate order. London: Routledge and Kegan Paul, 1978.

Bransford, J. D. Human cognition. Belmont, Cal.: Wadsworth, 1979.

Brentano, F. Psychologie vom empirischen Standpunkt. Leipzig: Duncker & Humblot, 1874. Ed. by O. Kraus, Trans. by L. McAlister as Psychology from an empirical standpoint. New York: Humanities Press, 1973.

Bronowski, J. The origins of knowledge and imagination. New Haven: Yale University Press, 1978.

Campbell, D. T. Unjustified variation and selective retention in scientific discovery. In F. J. Ayala & T. Dobzhansky (Eds.), Studies in the philosophy of biology. New York: Macmillan, 1974.

Cassirer, E. Substance and function and Einstein's theory of relativity. Chicago: Open Court, 1923.

Cassirer, E. The philosophy of symbolic forms, Vols. I, II, III. New Haven: Yale University Press, 1953, 1955, 1957.

Chomsky, N. Syntactic structures. The Hague: Mouton, 1957.

Chomsky, N. Aspects of the theory of syntax. Cambridge, Mass.: M.I.T. Press, 1965.

Craik, K. The nature of explanation. Cambridge, Mass.: Cambridge University Press, 1943.

Dewan, E. M. Consciousness as an emergent causal agent in the context of control system theory. In G. G. Globas, I. Savodnik & G. Maxwell (Eds.), Consciousness and the brain. New York: Plenum Press, 1976.

Dixon, T. R., & Horton, D. L. (Eds.). Verbal behavior and general behavior theory. Englewood Cliffs, N.J.: Prentice-Hall, 1968.

Eccles, J. C. The understanding of the brain. New York: McGraw-Hill, 1973.

Edelman, G. M. Group selection and phasic reentrant signaling: A theory of higher brain function. In G. M. Edelman & V. B. Mountcastle (Eds.), The mindful brain. Cambridge, Mass.: M.I.T. Press, 1978.

Enlow, D. The human face: An account of the postnatal growth and development of the cranofacial skeleton. New York: Harper & Row, 1968.

Ferguson, A. An essay on the history of civil society. London: A. Millar & T. Caddel, 1767.

Ferguson, A. Institutes of moral philosophy. Edinburgh: A. Kincaid & J. Bell, 1785.

Ferguson, A. Principles of moral and political science (2 Vols.). Edinburgh: A. Kincaid & J. Bell, 1792.

Feyerabend, P. K. Against method. London: New Left Books, 1975.

von Foerster, H. Biologic. In E. E. Bernard & M. R. Care (Eds.), Biological prototypes and synthetic systems (Vol. 1). New York: Plenum Press, 1962.

Foucault, M. The order of things. New York: Random House, 1970.

Fowler, C. A., & Tarvey, M. T. Observational perspective and descriptive level in perceiving and acting. In W. B. Weimer & D. S. Palermo (Eds.), Cognition and the symbolic processes (Vol. II). Hillsdale, N.J.: Lawrence Erlbaum Associates, 1982.

Gabor, D. Microscopy by reconstructed wave fronts. Proceedings of the Royal Society, 1949, A197, 454-487.

Gabor, D. Holography, 1948-1971. Science, 1972, 177, 299-313.

Gray, J. N. F. A. Hayek and the rebirth of classical liberalism. Literature of Liberty, 1982, V(4), 19-104.

Goody, J. The domestication of the savage mind. Cambridge, Mass.: Cambridge University Press, 1977.

Gregg, R. B. Rhetoric and knowing: The search for perspective. The Central States Speech Journal, 1981, 32, 133-144.

Gregg, R. B.

Hanson, N. R. A piecture theory of theory meaning. In R. G. Colodny (Ed.), The nature and function of scientific theories. Pittsburgh: University of Pittsburgh Press, 1970.

Hayek, F. A. Individualism and economic order. Chicago: University of Chicago Press, 1948.

Hayek, F. A. The sensory order. Chicago: University of Chicago Press, 1952.

Hayek, F. A. Studies in philosophy, politics, and economics. New York: Simon & Schuster, 1967.

Hayek, F. A. Law, legislation, and liberty (Vol. II). Chicago: University of Chicago Press, 1976.

Hayek, F. A. New studies in philosophy, politics, economics, and the history of ideas. Chicago: University of Chicago Press, 1978.

Hayek, F. A. The sensory order after 25 years. In W. B. Weimer & D. S. Palermo (Eds.), Cognition and the symbolic processes (Vol. II). Hillsdale, N.J.: Lawrence Erlbaum Associates, 1982.

Hering, E. Zur Lehre vom Lichtsinne. Leipzig: Englemann, 1978.

Hubel, D. H., & Wiesel, T. N. Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. *Journal of Physiology*, 1962, *160*, 106-154.

Hubel, D. H., & Wiesel, T. N. Receptive fields and functional architecture of monkey striate cortex. *Journal of Physiology*, 1968, *195*, 215-243.

Hurvich, L. M., & Jameson, D. Perceived color, induction effects, and opponent-response mechanisms. *Journal of General Physiology*, 1960, *43*, 63-80.

Kirzner, I.

Kirzner, I. *Competition and entrepreneurship*. Chicago: University of Chicago Press, 1973.

Kubler-Ross, E. *On death and dying*. New York: Macmillan, 1969.

Kuhn, T. S. *The structure of scientific revolutions* (rev. ed.). Chicago: University of Chicago Press, 1970.

Kuhn, T. S. *The essential tension*. Chicago: University of Chicago Press, 1977.

Kulpe, O. *Einleitung in die Philosophie*. Leipzig, 1895. Translated by R. Pilsbury & E. B. Titchener as *Introduction to Philosophy*. London: Swan Sonnenschein, 1897.

Lashley, K. S. *Brain mechanisms and intelligence*. Chicago: University of Chicago Press, 1929.

Lashley, K. S. The problem of serial order in behavior. In L. A. Jeffress (Ed.), *Cerebral mechanisms in behavior*. New York: Wiley, 1951.

Lenneberg, E. _Biological foundations of language_. New York: Wiley, 1967.

Lettvin, J. Y., Maturana, H. R., McCulloch, W. S., & Pitts, W. H. What the frog's eye tells the frog's brain. _Proceedings of the Institute of Radio Engineering_, 1959, _47_, 1940-1951.

Lloyd, G. E. R. _Magic, reason and experience_. Cambridge, Mass.: Cambridge University Press, 1979.

Mahoney, M. J. Psychotherapy and human change processes. In J. H. Harvey & M. M. Parks (Eds.), _Psychotherapy research and behavior change_. Washington, D.C.: APA, 1982. Pp. 73-122.

Maturana, H. R. Autopoesis: Reproduction, heredity and evolution. In M. Zeleny (Ed.), _Autopoesis, dissipative structures, and spontaneous social orders_. Boulder, Colo.: Westview, 1980.

Maxwell, G. Theories, perception, and structural realism. In R. G. Colodny (Ed.), _The nature and function of scientific theories_. Pittsburgh: University of Pittsburgh Press, 1970.

Menger, K. _Principles of economics_. Translated by J. Dingwall & B. F. Hoselitz. Glencoe, Ill.: Free Press, 1950.

Mises, L. _Human action_. New Haven, Conn.: Yale University Press, 1949.

Mises, L. Epistemological problems of economics (translated by G. Riesman). New York: , 1960. Originally _Grund probleme der National okonomie_, 1933.

Mowrer, O. H. _Learning theory and the symbolic processes_ (2 Vols.). New York: Wiley, 1960.

von Neumann, J. The general and logical theory of automata. In L. A. Jeffress (Ed.), _Cerebral mechanisms in behavior_. New York: Wiley, 1951.

von Neumann, J. The computer and the brain. New Haven: Yale University Press, 1958.

von Neumann, J. Theory of self-reproducing automata. (Ed. by A. W. Burks). Urbana, Ill.: University of Illinois Press, 1966.

Osborn, M. The archetypal metaphor in rhetoric: The light-dark family. In R. L. Scott & B. L. Brock (Eds.), Methods of rhetorical criticism: A 20th century perspective. New York: Harper & Row, 1972, pp. 383-400.

Pattee, H. H. Physical problems of the origin of natural controls. In A. Locker (Ed.), Biogenesis, evolution, homeostasis. Heidelberg: Springer-Verlag, 1973.

Pattee, H. H. Dynamic and linguistic modes of complex systems. International Journal of General Systems, 1977, 3, 259.

Pattee, H. H. Symbol-structure complementarity in biological evolution. In E. Jantsch (Ed.), The evolutionary vision. Boulder, Colo.: Westview, 1981.

Penfield, W. The mystery of the mind. Princeton, N.J.: Princeton University Press, 1975.

Penfield, W., & Roberts, L. Speech and brain mechanisms. Princeton, N.J.: Princeton University Press, 1959.

Polanyi, M. The logic of liberty. Chicago: University of Chicago Press, 1951.

Polanyi, M. Personal knowledge. New York: Harper & Row, 1958.

Polanyi, M. The tacit dimension. Garden City, N.J.: Doubleday, 1966.

Polanyi, M. Knowing and being. Chicago, Ill.: University of Chicago Press, 1969.

Popper, K. R. The logic of scientific discovery. New York: Harper & Row, 1959.

Popper, K. R. The open society and its enemies (Rev. ed.). New York: Harper & Row, 1962.

Popper, K. R. Conjectures and refutations. New York: Harper & Row, 1963.

Popper, K. R. Normal science and its dangers. In I. Lakatos & A. Musgrave (Eds.), Criticism and the growth of knowledge. Cambridge: Cambridge University Press, 1970.

Popper, K. R. Objective knowledge: An evolutionary approach. Oxford: Oxford University Press, 1972.

Popper, K. R. The open universe: An argument for indeterminism. (Ed. by W. W. Bartley, III.) Totowa, N.J.: Rowman and Littlefield, 1982.

Post, E. L. Formal reductions of the general combinitorial decision problem. American Journal of Mathematics, 1943, 65, 197-215.

Pribram, K. H. The brain. Psychology Today, 1971a, 5, 44-48; 88-90.

Pribram, K. H. Languages of the brain. Englewood Cliffs, N.J.: Prentice-Hall, 1971b.

Pribram, K. H. Some comments on the nature of the perceived universe. In R. Shaw & J. D. Bransford (Eds.), Perceiving, acting and knowing. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1977.

Prigogine, I. From being to becoming: Time and complexity in physical sciences. San Francisco: Freeman, 1980.

Prigogine, I. Time, ineversibility, and randomness. In E. Jantsch (Ed.), The evolutionary vision. Boulder, Colo.: Westview, 1981.

Ross, J. R. Constraints on variables in syntax. Unpublished doctoral dissertation, M.I.T., 1967.

Russell, B. Freedom versus organization. 1934.

Russell, B. A history of Western philosophy. New York: Simon & Schuster, 1945.

Sampson, G. Liberty and language. Oxford: Oxford University Press, 1979.

Schumpeter, J. A. A history of economic analysis. New York: Oxford University Press, 1954.

Shaw, R., & McIntyre, M. Algoristic foundations to cognitive psychology. In W. B. Weimer & D. S. Palermo (Eds.), Cognition and the symbolic processes. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1974.

Simon, H. A. The sciences of the artificial. Cambridge: M.I.T. Press, 1969.

Sokolov, E. Neuronal models and the orienting reflex. In M. A. B. Brazier (Ed.), The central nervous system and behavior. New York: Josiah Macy Foundation, 1960.

Solomon, R. L. The opponent-process theory of acquired motivation: The costs of pleasure and the benefits of pain. American Psychologist, 1980, 35, 691-712.

Sperry, R. W. A modified concept of consciousness. Psychological Review, 1969, 77, 532-536.

Sperry, R. W. Mental phenomena as causal determinants in brain function. In G. G. Globus, I. Savodnik & G. Maxwell (Eds.), Consciousness and the brain. New York: Plenum Press, 1976.

Steiner, G. After Babel. London: Oxford University Press, 1975.

Teuber, H. L. Perception. In J. Field, H. W. Magoun & V. E. Hall (Eds.), Handbook of physiology, section 1, neurophysiology (Vol. 3). Washington, D.C.: American Physiological Society, 1960.

Thom, R. Structural stability and morphogenesis. Reading, Mass.: W. A. Benjamin, Inc., 1975.

Turvey, M. T. Preliminaries to a theory of action with reference to vision. In R. Shaw & J. D. Bransford (Eds.), Perceiving, acting, and knowing. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1977.

Watkins, J. W. N. Against normal science. In I. Lakatos & A. Musgrave (Eds.), Criticism and the growth of knowledge. Cambridge: Cambridge University Press, 1970.

Weimer, W. B. Psycholinguistics and Plato's paradoxes of the Meno. American Psychologist, 1973, 28, 15-33.

Weimer, W. B. Overview of a cognitive conspiracy: Reflections on the volume. In W. B. Weimer & D. S. Palermo (Eds.), Cognition and the symbolic processes. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1974.

Weimer, W. B. The psychology of inference and expectation. In G. Maxwell & R. M. Anderson, Jr. (Eds.), Induction, probability, and confirmation. Minneapolis, Minn.: University of Minnesota Press, 1975.

Weimer, W. B. Manifestations of mind: Some conceptual and empirical issues. In G. G. Globus, I. Savodnik & G. Maxwell (Eds.), Consciousness and the brain. New York: Plenum, 1976.

Weimer, W. B. A conceptual framework for cognitive psychology: Motor theories of the mind. In R. Shaw & J. D. Bransford (Eds.), Perceiving, acting, and knowing. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1977.

Weimer, W. B. Notes on the methodology of scientific research. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1979.

Weimer, W. B. For and against method: Reflections on Feyerabend and the foibles of philosophy. Pre/Text, 1980, 1-2, 161-203.

Weimer, W. B. Ambiguity and the future of psychology: Meditations Leibniziennes. In W. B. Weimer & D. S. Palermo (Eds.), Cognition and the symbolic processes (Vol. II). Hillsdale, N.J.: Lawrence Erlbaum Associates, 1982a.

Weimer, W. B. Hayek's approach to the problems of complex phenomena: An introduction to the theoretical psychology of The sensory order.

Weimer, W. B. CCR is not completely confused rhetoric (and there is no need to "pan" it). In Proceedings of the XIth International Conference on the Unity of the Sciences (Philadelphia, 1982). New York: International Cultural Foundation, 1983.

Weimer, W. B., & Palermo, D. S. (Eds.). Cognition and the symbolic processes. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1974.

Wundt, W. Ethics. London: Swan Sonnenschein. New York: Macmillan, 1902.

Zeleny, M. Autopoesis: A paradigm lost? In M. Zeleny (Ed.), Autopoesis, dissipative structures, and spontaneous social orders. Boulder, Colo.: Westview, 1980.

[1]Self Producing Systems. Self production is pervasive in the biological realm, and appears to have no direct counterpart in purely physical systems (apparent exceptions such as crystal formation or precipitation do not count because one crystal does not produce another, rather crystals precipitate out of a complex solution). A similar phenomenon is self regulation, or mutual entrainment, between physical systems. Entrainment produces an order in which all the parts of a system are interdependent and regulate each other. These two instances of autopoetic or self producing orders are interesting transitional cases to spontaneous orders because they do not exhibit creativity. Consider mutual entrainment as a transition to the degree of complexity we are interested in.

Leibniz was apparently the first to notice that pendulum clocks on opposite sides of a thin wall come to beat in harmony with each other no matter how they were initially set. Similarly it is well known that the pulse and respiration patterns of lovers in close physical contact will tend to move toward common values, and sometimes lock in phase like Leibniz's clocks (unless the rates are close together to begin with all that will be observed is a tendency for the slower to speed up, and the faster to slow down. Nonetheless this is one physiological reason that love is described as both leaving one faint, and alternately producing a rapid heart beat, etc.). Perhaps the best example in a physical system is the grid of interconnected electric power generators in the United States (except Texas). As Dewan (1976) noted, these generators are locked in step to produce the same current output because, if one lags behind it is driven like a motor to catch up by all the others, and similarly one that surges ahead will be pulled down because it will be powering all the others. Thus a common output is regulated by the interconnections of the grid. In this manner a complex feedback process can produce stable, or regulated, equilibrium.

Similarly autopoetic regulation in biology produces entities that are like themselves (Maturana, 1980). These systems exhibit rhythmic differentiation, but no creativity (unless the regulatory process fails). Zeleny (1980) provides a generalized definition:

> An autopoetic system is a distinguishable complex of component-producing processes and their resulting components, bounded as an autonomous unity within its environment, and characterized by a particular kind of relations among its components and component-producing processes: The components, through their interaction, recursively generate, maintain, and recover the same complex of processes which produced them (p. 4).

Maturana coined the term autopoesis to deal with the origin of living systems, and has used the concept to explain cellular division, and heredity and genetics.

While fruitful in the systems approach to biology (and control theory), Maturana would like autopoesis to solve the problem posed by cognition. As he (1980) said,

> The problem of cognition, if it is to be treated as a biological problem in its own right, requires the specification of the relations that hold between the living system as a cognitive system and that which it is supposed to know,... Characterization of living systems as autopoetic systems permits [one] to deal with these...problems, ... (p. 77).

But autopoesis does not solve the problems of cognition: Cognition is creative, biology is not--except in <u>accidents</u> like random genetic mutation. If this is really the solution for biology then it is also an argument for the independence of psychology, which must deal with a separate phase of existence (see Weimer, 1976; Pattee, 1981).

<u>Dissipative Structures, Order by Fluctuation, and Catastrophe</u>. Of far more obvious relevance to the psychological and social spontaneous orders are the essentials of Ilya Prigogine's (Nicholis & Prigogine, 1977; Prigogine, 1980, 1981) nonequilibrium thermodynamics and Rene Thom's (1975) mathematical formulation of catastrophe theory. These theories represent a step away from stable equilibrium models lacking in creativity. Both theories provide objective models of how complex orders can leap over a threshold to a new form of dynamic organization. Prigogine's approach to "order by fluctuation" emphasizes that while the second law of thermodynamics (the entropy law) may hold for isolated systems such as the universe as a whole it does not describe the behavior of systems in interaction, that can decrease entropy and increase self-organization. Consider nonequilibrium thermodynamics as one mechanism for creative restructuring of a system.

When a system with feedback loops in the interaction mechanisms acting between its elements takes in matter or energy from outside itself, the input matter or energy can disrupt equilibrium and drive the system to a new state. Prigogine calls such new states dissipative structures, and emphasizes that they result from a combination of deterministic and chance factors. The random factors become crucial when the system is at or very near the threshold points for the emergence of new organizations. These points are bifurcation points: between two bifurcation points the system follows regular "laws" that are (Macro) deterministic, but at the bifurcation points fluctuations, or random deviations from the (statistical) averages, throw the system into another mode of stable organization. Thus the "revolutionary" restructuring of a domain is brought about or ordered by fluctuation when a bifurcation point is reached. Prigogine and his associates have applied this basic conception of differentiation to phenomena ranging from the behavior of chemical solutions to the growth of urbanization (Allen & Sanglier, 1980; Allen, 1981).

Allen (1981) summarizes a key point:

> Between two bifurcation points, the system follows deterministic laws (such as those of chemical kinetics), but near the points of bifurcation it is the fluctuations which play an essential role in determining the branch that the system chooses. Such a point of view introduces the concept of 'history' into the explanation of the state of the system (p. 29).

Throughout all the complex orders we find a timeless analysis is totally inadequate to explain development. Spontaneous complex orders are rate dependent, and thus require an historical approach, that takes account of particular sequences, for an adequate understanding. Understanding any complex phenomenon requires understanding its history of differentiation through time. Once again this requires that we abandon the goal of predictability that characterized classical inquiry into simple phenomena. As Prigogine (1981) noted,

> For a long time, classical mechanics with its absolute predictability has shaped our image of the physical world. Over the last three centuries, however, this image has evolved towards a more subtle conception in which both deterministic and random features play essential roles (p. 80).

Prigogine and Bohm (1978) are forcing us to recognize that even the "simple" physical sciences are much more complex than our classical accounts can address.

The requirement that we include history and abandon prediction does not mean that we must be limited to historical narrative in understanding spontaneous orders. Prigogine's approach is highly mathematical, and the theory of Thom is strictly mathematical. Consider catastrophe theory as an attempt to specify how orders may differentiate in time.

Rene Thom's (1975) mathematical approach to the treatment of order by fluctuation attempts to show that the stability of a dynamic structure is maintained by the existence of a context of constraints (control factors, "attractors") that assure that the system will not evolve randomly by providing loci of equilibrium. Seen geometrically these loci provide a surface over which the system evolves. Because the loci (themselves) change the equilibrium surface also changes. If a sufficiently large disturbance perturbs the system, the attractors may fail to exert their controlling function, and the resulting discontinuity in the equilibrium plane is a catastrophe. After a catastrophe redirects the behavior of the system new "attractors" provide a different systemic identity that stabilizes development until the next catastrophe occurs. The similarity to the phenomena studied by Prigogine is obvious.

The problem for a mathematical theory of catastrophe is to describe the configuration of all possible equilibrium surfaces formed by attractors. Thom's classification theorem indicates that there are only seven "elementary catastrophes" that can exist in any system having four or less parameters (such as the 4 dimensional space-time manifold). Thus these seven types of catastrophe (or combinations thereof) should provide a useful description for systems that induce dynamic regulation by fluctuation or catastrophic change at a bifurcation point.

[2]This point was made 50 years ago by Mises (1960), especially pp. 116-118. Mises pointed out that economics (as a domain of essential complexity) can indeed make predictions, but only qualitatively. The particulars (in economics, the concrete value judgments of individuals) can appear only as ex post facto data, never as predicted occurrances. As Mises noted,

> That we are unable to foretell their concrete configuration is due to the fact that we here come up against a boundary beyond which all scientific cognition is denied to us. Whoever wants to predict valuations and volitions would have to know the relationship of the world within us to the world outside us. Laplace was unmindful of this when he dreamed of his cosmic formula (p. 118).

[3]The understanding of language emerging from contemporary linguistics is neither causal nor predictive. The transformational approach explains the surface phenomena of language by deriving them from abstract underlying rules of determination that specify how deep conceptual entities (such as S, understood intuitively as "sentence") are constrained to appear in their eventual surface realization. It traces the derivational

history of an utterance in terms of the successive rewrite rules that change S into whatever surface form emerges (this is conceptual as opposed to temporal history except for phonology). Such explanations make manifest how an infinite number of sentences can arise from a finite number of syntactic rules in conjunction with the finite words of a language. Creativity or productivity, the ability to make novel but appropriate sentences (and to comprehend them), is a matter of recursive syntactic structuring according to rules of varying degrees of generative power.

While the linguist can understand how an infinite variety of sentences can be generated he or she can never predict either what word or sentence a speaker will utter next, nor make any inference from linguistic theory as to the cause of any utterance. Such information is beyond the bounds of understanding in a complex order such as language, and one hallmark of Chomsky's "transformational revolution" is the disappearance of attempts to provide causal and predictive accounts of the particulars of language (see Dixon & Horton, 1968; Weimer & Palermo, 1974). To relate this to points developed below, language is an example of a cosmos rather than a taxis, and the rules that are most important are negative prohibitions rather than positive prescriptions of particulars (cf. the well known dissertation of J. R. Ross [1967] entitled, "Constraints on variables in syntax"). So far as prediction is concerned, past utterances are like prices in the market--mere historical data that provide no basis for prediction. Sentences, like prices, provide information to act upon but are not predictive. And one can no more "experiment" with language than with prices in a market--all such intervention falsifies the spontaneous order, turning the cosmos into an experimenter defined taxis.

[4] Some definitions are in order for terms contrasting spontaneous complex orders and man made simple orders. A _taxis_ is an organization designed to fulfill particular purposes specified in advance. The contrasting term for a spontaneous order with no purpose is a _cosmos_. See Hayek, 1978: "An arrangement produced by man deliberately putting the elements in their place or assigning them distinctive tasks [the Greeks] called _taxis_, while an order which existed or formed itself independently of any human will directed to that end they called _cosmos_" (p. 73). _Catallaxy_ is Hayek's term for the market order as a spontaneous order in opposition to the term economy which, since Aristotle, has referred to the organization or management of a taxis. Polanyi (1951) introduced the terms monocentric and polycentric to refer to the control structures (or organizational basis) of a taxis and cosmos, respectively. A cosmos is polycentric in the sense that it embodies multiple loci of control, i.e., is decentralized, whereas a taxis is "directed" by a specifiable chain of command originating from one source. Note that taxis organization must always be limited to the conscious, explicit commands of a chief executive, while a cosmos, with decentralized and therefore not necessarily conscious control, is not so limited. A cosmos can take advantage of the superior information processing capacity of the tacit dimension, a theme Polanyi later elaborated with regard to individual psychology and personal knowledge (1958, 1966).

[5] Bronowski saw the taxis mentality in automata theory and argued against it in this fashion:

> If the brain were separated from the body--and this is the essential fallacy in the Descartes duality of mind and body--if the brain were

> separated from the body and were fed with the information of the senses and then the output went out to the muscle, then the brain by ordinary quantum physics would have to come up with one of a finite number of answers. Then the brain would be a finite state machine, it would be a digital computer, and it would be enmeshed in all the paradoxes of digital computers. But the point is that you have reached this artificial position because you have put the brain into a box, you have fed the information into this box, and now you have asked it for an answer. As soon as you challenge the box for an answer, then it is bound to print one of a number of digits--you have converted it artificially into a Turing machine (p. 101).

In addition to being a cosmos instead of a taxis the brain is not just a digital machine, as we shall note in the next section.

[6]Thus we may legitimately be skeptical of remarks such as those of Simon (1969) that "A man, viewed as a behaving system, is quite simple. The apparent complexity of his behavior over time is largely a reflection of the complexity of the environment in which he finds himself" (p. 25). Anyone who understands the primacy of the abstract, the conceptual nature of facts, and the sense of the idealistic theme that the knowledge we possess of the environment is "in" the mind of man rather than the environment, may legitimately view such remarks as question begging scientism. It is alright to adopt such a position as a research strategy, to attempt to falsify it, but one must guard against supporting the thesis either by artificial experiments or presupposing it. Simon's conclusion may be a bit premature:

> They [experimental results of 'Thinking'] are simple things, just as our hypothesis led us to expect. Moreover, though the picture will continue to be enlarged and clarified, we should not expect it to become essentially more complex. Only human pride argues that the apparent intricacies of our path stem from a quite different source than the intricacy of the ant's path (p. 53).

It is not just human pride, but the evolution of complexity that is incomprehensible to the engineering mentality.

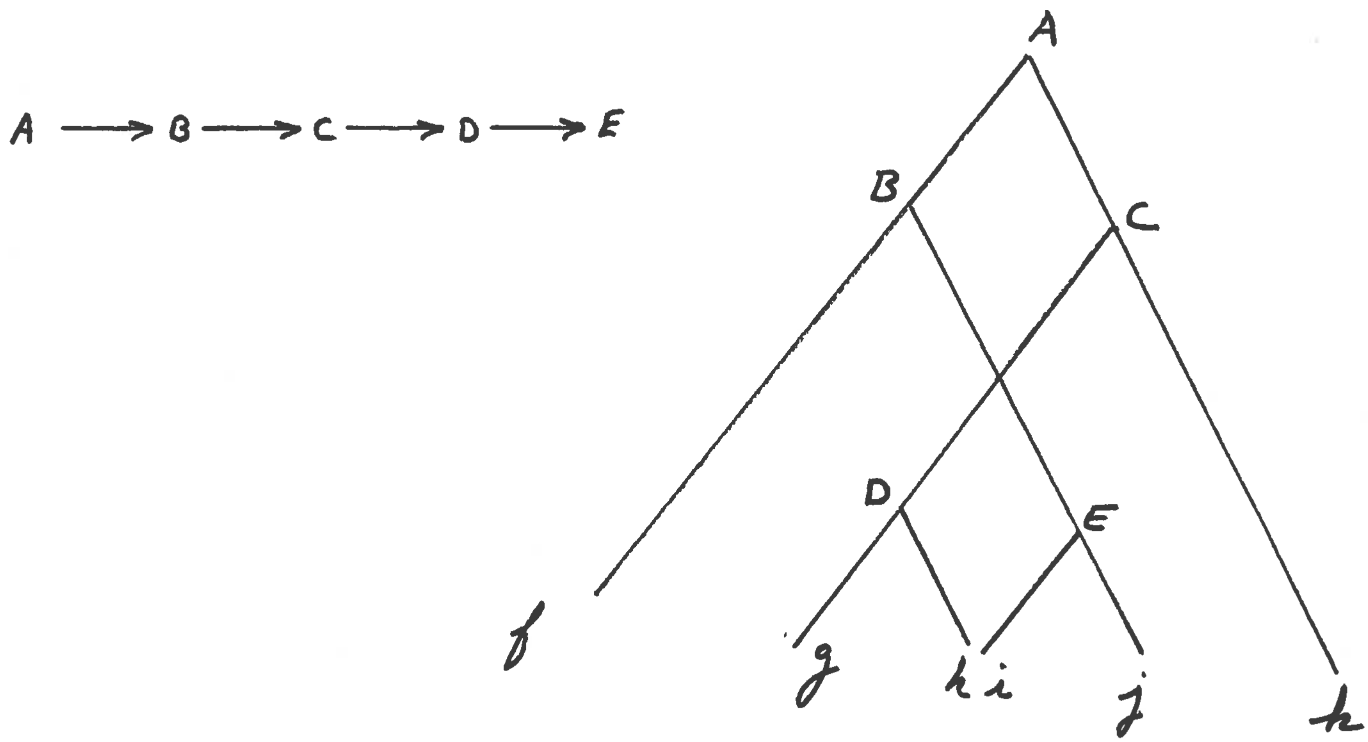

Fig. 1

Chaining or associational control (left) compared to hierarchical structuring

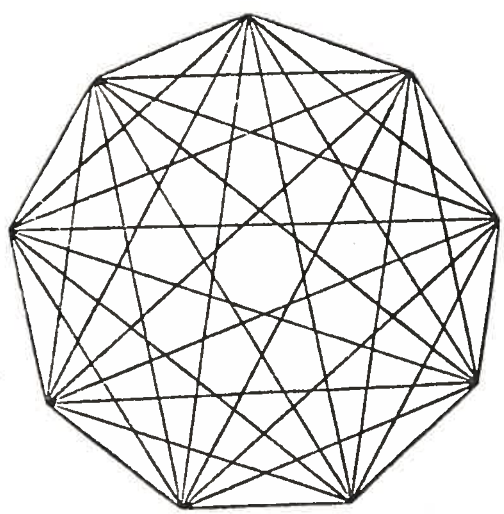

FIG. 2.

Polanyi's representation of polycentric control

(From Polanyi, 1951)