5.
How Useful Is the Complexity Paradigm Without Quantifiable Data? A Test Case: The Patronage of 5th-6th Century Buddhist Caves in India

*Richard S. Cohen**

Abstract. Starting from E. B. Tylor's inaugural definition of culture, anthropologists and sociologists have struggled with what it means for culture (or society) to be a "complex whole." In order to maintain culture's wholism, cultural relativists and positivists have been forced to artificially limit the range of meanings that might attach to cultural symbols or values. The paradigm of complex adaptive systems may escape the shortcomings of relativist and positivist wholisms, for within this model meaning is not limited by scholarly fiat. Rather, the limitation of meaning is a function of these systems' inner-processes. Superabundant meaning is the store of adaptive potential and plays a crucial role in the functioning of complex adaptive systems. For a system to be complex, whole, and adaptive it must necessarily achieve the poised state at the edge of chaos. A monastic site founded in Western India during the late fifth century is examined as a way to explore culture as a complex adaptive system through Kauffman's model of self-organization, forcing structures, canalyzing rules, and chaos. Symbolic values coalesce into a system that is simultaneously homeostatic and capable of change. The range of any sign's meaning is potentially infinite. Yet as meaning is pragmatically realized in action this range is vastly reduced to a tiny sub volume of its potential, allowing for stability on the edge of chaos.

1. Introduction

In Ann Arbor, where I live, there is a small bookstore named Shaman Drum. This store specializes in scholarly publications in the humanities, with a special emphasis on the study of religion, my own field. Shaman Drum has no section for the sciences, nor do I imagine that many customers venture in searching for scientific texts. This is why I was surprised on a recent visit to see that Shaman Drum had stocked copies of M. Waldrop's introduction to complexity theory and Stuart A. Kauffman's *The Origins of Order*. More remarkable yet was where these texts were shelved: on the wall Shaman Drum dedicates to the nebulous field of "culture studies," nestled among Bourdieu, Foucault, Althusser, and Derrida. Thinking about this odd combination, I decided that it was appropriate. Robert Lowie has described culture itself as a thing of "shreds and patches" ([1], p. 5). And whether or not one agrees with Lowie about culture, this description does fit culture studies, which ranges from abstract and ideological studies of the culture concept to empirical treatments of phenomena deemed "cultural." Indeed, why not include Waldrop and Kauffman? The sciences

* Department of Religious Studies, Rhodes College (U.S.A.). E-mail: Cohen@ns.rhodes.edu.

of chaos and complexity are penetrating the popular imagination, most prominently perhaps in Steven Spielberg's blockbuster movie "Jurassic Park," where actor Jeff Goldblum presents chaos as the scientific explanation for the inescapable truth of Murphy's Law.

It seems that, for Shaman Drum, chaos and complexity can be shelved in the catch-all category that includes the latest intellectual fads. For scientists of chaos and complexity, however, this classificatory flippancy is not easily reconciled with the view of their field presented in the very texts Shaman Drum stocks. Waldrop's *Complexity*, written for a popular audience, grips its readers through prose filled with the expectancy of a science on the verge of discovering life's inner secrets. Kauffman is more straightforward. He suggests that complex systems can be adaptive if and only if they are poised at the edge of chaos, and that natural selection itself selects for just such poised systems. And he characterizes this latter proposition as a "bold hypothesis" ([2], p. 232), "terribly important" (p. 235), and, if true, a "deep law indeed" (p. 235). No intellectual fad here. Indeed, Kauffman concludes his masterwork by affirming that he suspects "with quiet passion" that he may be on the track to discovering the "fundamental principles of order any life would reexpress" (p. 645). These are positive claims with which few scholars engaged in culture studies would feel at home, let alone accept.

Nevertheless, there is an argument to be made for linking Waldrop, Kauffman, and complexity to the study of culture. As a critical discipline, culture studies' origin is often traced to a single vastly important definition of "culture" published in 1871 by E. B. Tylor on the first page of his *Primitive Culture:*

> Culture or Civilization, taken in its widest ethnographic sense, is that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society.

As historian of culture Christopher Herbert rightly observes, "the crux of this definition, the locus of both its radical modernity and (if this is not redundant) its inescapable instability, lies in the phrase 'complex whole,' which at first glance seems precisely to banish all instability" ([1], p. 4). If the notion of a "complex whole" is the central problem in the study of culture, it is also fundamental to Kauffman's own project, which seeks to explain "what is a functional whole and how does it transform when its components are altered" ([2], p. 370). Though Kauffman does not use the word "complex" here, his solution relies upon notions of complexity: for a system to be both whole and dynamic, it must also be complex. In short, the foundational definition of culture and the ongoing critique of this definition work within much the same semantic field as current discourse in the sciences of complexity.

Is the apparent semantic overlap between the study of culture and that of complexity a mere coincidence inspiring a perverse analogy? Or may Kauffman's suspected "fundamental principles of order" apply as much to the social and cultural contexts within which life persists as to life itself? That is, does the complex adaptive system paradigm have heuristic value for modeling social and cultural phenomena as comprising a complex whole? This latter question is bound up with another, namely, *how* can a scholar within the humanities apply the proposition that systems may be both complex wholes and dynamically adaptive to their subject matters? The complex adaptive systems paradigm is typically presented through genetic algorithms of various sorts — cellular automata, *NK* Boolean Networks, etc. — which manipulate precise numerical data through explicit (albeit dynamic) operational rules. Human societies and cultures can never be so clearly encapsulated. Is the complex adaptive system paradigm, and its potentially universal ramifications, therefore, methodologically inaccessible to scholars in the humanities?

The paper's title announces that I will address these questions through a test case: the patronage of 5th and 6th century Buddhist caves in India. One topic I will not address at any length, however, is 5th and 6th century Buddhist caves in India. Although my own research in the history of Buddhism centers on these caves, my paper's title is something of a red herring. I will discuss my findings from India only insofar as they provide examples through which to elaborate the paper's broader theoretical agenda. In accord with my two principal foci, the paper will be divided into two sections. The first explores what it means for something to be complex and whole according to the complex adaptive systems model; the second will explore how this paradigm can have value for scholars who lack quantifiable data, and therefore are not able to intricately model complex adaptive systems of their own.

2. Complex Adaptive Systems as Complex Wholes

The definition of culture as a complex whole presented in Tylor's work had its first great redactor in the person of Marcel Mauss. A sociologist and anthropologist, Mauss began his classic *The Gift* with a statement of his interest in unraveling social phenomena that "contain all the threads of which the social fabric is composed" ([3], p. 1). Mauss's work commenced with an image of the "social fabric," a "weave," suggesting society as a historically textured but unchanging construct. By the finale, however, this textile metaphor was set aside in favor of the more dynamic images of "systems in motion" and "active forces submerged in their environments" ([3], p. 78). For Mauss, the study of society, involved "something more than a set of themes, more than institutional elements, more than institutions, more even than systems of institutions divisible into legal, economic, religious and other parts" (p. 77). The sociologist and anthropologist was instead "concerned with 'wholes,' with systems in their entirety," for only by considering a society or culture within the whole is one able to see its essence, its operations and its living aspects.

To accomplish this task, Mauss recommends that scholars see society "as an engineer sees masses and systems" (p. 78). When making this recommendation Mauss likely had as his model the study of thermodynamic systems, which understands its objects of analysis to be closed orders, either at equilibrium or close to and advancing towards that static state. This paradigm allows for a certain simple elegance to the consideration of a complex domain. The social world can then be calculated as the sum of a complex of variant and invariant elements and their mutual relationships. It can be studied and understood "mathematically," using a "Calculus-of-Sociology" whose differential equations track the mutual influence of individual variables in flux.

Even if this equilibrium model was not precisely what Mauss had in mind, however, the history of post-Maussian sociology and anthropology as told by Christopher Herbert suggests that such was his legacy. According to Herbert, it has become almost a "self-evident truth" that culture is a system "each factor of which is in some sense a corollary of, consubstantial with, implied by, immanent in, all the others" ([1], p. 5). Historically, scholars have fallen into two camps vis-à-vis cultural systematics: the relativists and the positivists. Cultural relativists treat cultures as closed systems of meanings. Here, cultures are webs of significance whose constituent signs are fully interpretable, but whose "values are ascer-

tainable only as functions of the wholes within which they come into being" ([1], p. 8). Positivist scholars, like Malinowski and Radcliffe-Brown, see culture as a matter of "concrete, observable facts" (p. 10), rather than in the systemic interrelationships that link a people's values into a discernible whole. For these positivists, culture is not an imagined web of relationships binding facts; culture is either a thing itself, suitable for empirical examination, or nothing at all. The intellectual sparring between these two camps is fascinating, and is summarized in Herbert's monograph. What is important for us to recognize is that for both the relativists and positivists, culture is said to be "complex" as a function of the sheer multitude of factors that coexist within its whole. For instance, Tylor sees culture as the unification of social knowledge, belief, art, morals, law, and custom; Mauss, too, enumerates the social phenomena within his whole, which include the "legal, economic, religious, aesthetic, morphological, and so on" ([3], pp. 76-7). Moreover, cultural relativists and positivists alike understand such a complex abundance of cultural/social factors to comprise a "whole" because both understand the system of values these define to be closed and at equilibrium. For the relativists, cultural meaning is a function of the totality of all cultural factors, and can never exceed that totality. For the positivists, meaning is a function of empirical facts, and has value only insofar as it corresponds to those facts, again without excess. In both cases, total systemic entropy is ideally fixed.

As Herbert indicates, current critiques of culture treat this concept as "infested with logical incoherence" ([1], p. 21), for both the relativist and positivist approaches tend towards infinite regress under direct analysis of their presuppositions. The trouble is, in short, that cultural meaning is not a closed system, either internally or externally. That is, meaning is not solely a function of an integral whole or empirical facts, but transcends closed systemic boundaries; the whole can never account for all possible meaning, and cannot be truly whole. This, of course, is a fuzzy way of restating Gödel's proposition that "given *any* consistent set of arithmetical axioms, there are true arithmetical statements that cannot be derived from the set" ([4], pp. 58-9). In many ways the principal question of the present conference is whether and how the highly functional concept of a complex whole can be rescued in the face of Gödel's insight. And in large part we have gathered because we agree that complexity theory, the model of the complex system at the edge of chaos, enables us to discuss things like societies and cultural systems without requiring us to take shelter in the untenable wholisms of the relativist and the positivist.

To preserve the complex whole as a functional construct, the complex adaptive system paradigm requires that one understand complexity and wholeness in a new way. For relativists and positivists, complexity is a matter of sheer numbers; the whole is calculated through a closed set of differential equations. Perhaps such an approach could profitably be applied by an Annalist studying the *longue durée*, but it seems inappropriate to the tumult of a physical or social system in dynamic process. Real-world systems are not closed off from outside influences; they are not closed. Indeed, social and cultural systems are successful only insofar as they are complex and whole and adaptive, adaptivity being precisely that quality of a system which enables it to remain complex and whole while it dynamically develops in relation to environmental pressures. Based largely upon the work of Stuart A. Kauffman, I would propose that certain systems are "complex" precisely because their potential for meaning or information exceeds apparent systemic limits; they are "whole" because they dynamically limit that excess without eliminating it; and they are "adaptive" because their self-definition incorporates self-transformation: meanings they hold *in potentia* constantly transgress systemic boundaries, become incorporated into the system, and displace other, established meanings, which in turn become evolutionary potential. Complex adaptive systems share many of the elements found in conventional systems, including a hierarchy of sub-structures, a range of dynamics contingent on initial conditions and environment, and a multitude of potential outcomes. The distinction between the two lies in the fact that complex adaptive systems display many of the orderly characteristics of equilibrium systems while in a far-from-equilibrium environment. Equilibrium-order based upon the local entropy is fixed, stable, set. But the orderly material and qualities of a complex adaptive system's non-equilibrium-order can change and adapt without necessarily losing their orderly character.

3. Kauffman on the Structure of Complex Systems

Kauffman's attempt to explain the behavior of complex adaptive systems comes within the broader context of his rethinking evolutionary theory. Kauffman observes that Darwin's legacy has been a belief in natural selection as the principal means by which orderly evolution proceeds: "Natural selection operating on gratuitous random mutations is the sieve that retains order and lets chaos pass into oblivion ... No idea derivative from Darwin lies deeper in our minds than this: myriad mutations, selection sifting" ([2], pp. 10-11). As an evolutionary biologist, Kauffman advances the view that "myriad mutations, selection shifting" is *not* the sole engine driving species individuation and survival.[1] Instead, living complex systems exhibit a tendency towards spontaneous order and self-organization, complementing selection. And Kauffman proposes that evolutionary theory can be revised in three stages:

> We must delineate the spontaneous sources of order, the self-organized properties of simple and complex systems which provide the inherent order evolution has to work with *ab initio* and always.
>
> We must understand how such self-ordered properties *permit*, *enable*, and *limit* the efficacy of natural selection. We must see organisms in a new light, as the *balance found*, the *collaboration achieved*, when natural selection acts to further mold order which preexists ...
>
> We must understand which properties of complex living systems *confer* on the systems their capacities to adapt ... Some systems can hardly adapt at all. Indeed, we must investigate the possibility that selection itself achieves the kinds of organisms which can adapt successfully. ([2], p. xiv)

That is to say, living systems *qua* complex adaptive systems are able to produce meaning and reproduce meaning within a dynamic (or even hostile) environment because they are constituted in such a way that the source of their order/identity is simultaneously the source of the adaptive variations upon which selection acts. In the Darwinian view, mutation is the Self becoming Other; selection, the Other becoming Self. In Kauffman's view, mutation is a realization of the Self's alternate potentialities; selection is the mechanism of

[1] Kauffman presents Robert Shapiro's startling testimony to the inadequacy of the strict Darwinian view, which holds mutation alone as sufficient cause for the production of beings as complex as ourselves. Shapiro's work has shown that if one were to attempt to duplicate a simple *E. coli* bacterium through random acts of mutation alone, the chances of success are "comparable to the chances that a tornado sweeping through a junkyard might assemble a Boeing 747 from the materials therein" ([2], p. 22).

the Self's reintegration. Before investigating how these insights can work within a discussion of culture, I wish to review Kauffman's explanation of these three stages: the spontaneous sources of order, the mechanism through which spontaneous order enables evolution, and the theoretic range of systems within which spontaneous order might function.

The conditions for systemic *complexity* and the mechanisms of *adaptivity* are two different matters. It is one of the most fundamental, functional, and wide-ranging of complexity science's insights, however, that the latter dynamic is not found absent the former. Self-organized order arises spontaneously in certain complex systems, and it is this order that is acted upon by the selective processes of adaptation and evolution. Accordingly, to comprehend adaptation one must first treat complexity, in particular questioning how complex systems give rise to self-organized order.

Complex systems are *complex* insofar as they incorporate a vast number of variables simultaneously playing many different roles in the system's evolution and following many different laws of behavior. These individual systemic elements will provide cybernetic regulation, at times homeostatic, at times mutative, resulting in a development of the system's overall dynamic. Whereas the existential details of complex systems are difficult of access, the fact that they are essentially composed of elements associated by relationships makes them simple to model. Indeed, Kauffman's main tools for studying complex systems are idealizations thereof, which he calls autonomous random Boolean *NK* networks. These incorporate a certain number of elements (N), a certain network of connections between those elements (K), certain rules governing those connections (Boolean functions), a random environment within which these three systemic elements "evolve," and finally an infusion of historical happenstance to simulate reality.

Because *NK* Boolean networks are "autonomous," the number of possible states into which the system might enter is delimited by the number of elements. That is, "since there is a finite number of states, the system must eventually reenter a state previously encountered; thereafter, since the system is determinist and must always pass from a state to the same successor state, the system will cycle repeatedly around this recurrent *state cycle*" ([2], p. 190). The potential length of any network's state cycle can range from 1 to as many as 2^N alternate states. During this duration, the system is fated to cyclically repeat its own past unless a mutation occurs in the element (random flipping of 1 to 0, or vice versa), in the Boolean function (e.g., an AND connection becoming an OR), or in the "physical" connections between the elements themselves. In the event of such random change, the system is potentially thrown off one state cycle to range onto a new one. In these terms, what we call "stability" or "order" can be seen as homeostasis, the property of a system that resists the effects of change due to random mutation or external force. For the human realm, John Holland's observation that "the immune system is so good at self-identification that, at present, it provides our best scientific means of defining individuality" ([2], p. 19) is as fascinating as it is suggestive. The psychologist might generalize, we *are* our defense mechanisms.

Systemic state cycles fall into three general phases described by Kauffman as the solid, chaotic, and complex. When the K value is greater than 2, the system tends towards chaos, for the "thickness" of the network allows the state cycle to follow what would appear a random path, unpredictable and erratic. Here, the effects of random mutation are perhaps indistinguishable from the general systemic behavior. When the connections between systemic elements are singular ($K = 1$), the system simply enters into a modular feedback loop. Such a system is highly resistant to change, but whatever mutations do occur will be catastrophic. Third, Kauffman describes networks where $K = 2$ as a kind of "phase transition" between chaos and order. This is the regime of complexity. At $K = 2$, systems are predominantly in the solid regime, possessed of a fixed periodic structure, their state cycles unaffected by all but major structural disturbances.

The basic characteristics of self-organized order in $K = 2$ nets are, first, that they have a very short state cycle relative to the number of elements in the system. In Kauffman's words, "their dynamical behavior (is spontaneously confined) to truly tiny sub volumes of their state space" ([2], p. 201). He explains:

> The expected median state cycle is about $\sqrt{N}$ ... A Boolean network with 10,000 elements which is utterly random within the constraint that each element is regulated by only two elements would therefore have a state space of $2^{10,000} = 10^{3000}$ but would settle down and cycle recurrently among a mere $\sqrt{10,000} = 100$ states ... A system of 10,000 elements which localizes its dynamical behavior to 100 states has restricted itself to 10^{-2998} parts of its entire space. Here is spontaneous order indeed. ([2], p. 201)

A second dynamic property is that $K = 2$ state cycles tend to be stable, and remain largely unmoved by minor disturbances: " ... most mutations in such networks alter the attractors only slightly. The ordered network regime is therefore characterized by a homeostatic quality: networks typically return to their original attractors after perturbations" ([2], p. 81).

Both of these dynamics of order *internal* to any individual state cycle have correlates in terms of the macroscopic family of all potential state cycles of a given *NK* Boolean net where $K = 2$. First, "a large fraction of the N elements, typically 70 percent or more, fall to a fixed active or inactive state which is *identical* on all alternative attractors of the Boolean network." Second, if a system flows to another state cycle due to a perturbation, in most cases it will always flow to the same alternate cycle, no matter what the perturbation or position on the state cycle: " ... a variety of different stimuli acting on different elements in the system induce the same specific response" ([2], p. 202). Here we reach the first tier of Kauffman's revision of evolutionary theory.

Now to the nitty-gritty of self-organized order. Kauffman asks, "What principles allow $K = 2$ networks to exhibit such profound order?" and answers his own query thus:

> The basic answer appears to be that such networks develop a connected mesh or *frozen core*, of elements, each frozen in either the 1 or 0 state. The frozen core creates spanning, or *percolating*, walls of constancy which break the system into functionally isolated islands of unfrozen elements cut off from influencing one another by the walls of frozen elements. The formation of such functionally isolated islands by a percolating frozen core appears to be a sufficient condition for order in Boolean networks; conversely, failure of a frozen core to percolate and leave functionally isolated unfrozen islands is a sufficient condition for chaos. (p. 203)

Kauffman's development of *NK* Boolean nets is predicated upon two coordinate assumptions: 1) The global activity of any particular network exists *in potentia* in the specific local features programmed; and 2) because this global activity is an emergent characteristic of the system, it cannot be discerned merely through a knowledge of those local features. Here we find that local features are not only the engine of systemic evolution but also that

evolution *works* in an orderly fashion precisely because all change arises initially in response to the immediate local environment. The popular bumper sticker, "Think Globally, Act Locally," may be more than mere slogan; rip-stop nylon may just be the cosmic fabric of the universe.

Two properties of a complex system can be shown to account for the percolating walls that give it order, creating the functionally isolated islands in which adaptation and evolution may occur without destroying that order. Kauffman calls the first, *forcing structures*, the second, *internal homogeneity clusters*. For simplicity I will present only the former:

> The defining feature of a forcing structure in a Boolean network is that, at each point, a single element has a single value which can force a descendent element to a specific value regardless of the activities of other inputs ... In order for a connection between two regulated elements to be classed as forcing, the second element must be governed by a canalyzing Boolean function[1] and the first element, which is an input to the second, must directly or indirectly ... be governed by a canalyzing Boolean function. ... More generally, forcing is a transitive relation such that if A forces B and B forces C, then A indirectly forces C via B. Forced values must propagate down a connected forcing structure. ... The forcing structures form a large interconnected web of elements ... This web falls to a fixed state, each element in its forced value, and leaves behind *functionally isolated islands of elements* which are not part of the forcing structure. ([2], p. 205)

To recap, this investigation of Kauffman's work began with the suggestion that a system's capacity to adapt is contingent upon its prior generation of spontaneous self-organized order. Not all systems display dynamic order — some careen off into the chaotic regime, some are orderly but lack the complexity requisite for meaningful systemic evolution. Order, we saw, is a system's spontaneous restriction of its own functionally infinite potentialities. The order of $K = 2$ Boolean networks in particular is characterized by spontaneous self-limitations in respect of the systemic structures from which response to perturbation arises, modes of response, responses, and the consequences of response. Finally we found that order arises spontaneously in this special set of Boolean networks as a result of forcing structures created by the systematic linking of select N elements into a lattice having a fixed value. The "percolation" of the web of ordered, set values leaves behind islands of modular, functionally isolated elements, which severally may be ordered or chaotic. Thus we begin to glimpse the mechanism by which a system's spontaneous crystallization of order simultaneously creates the condition for adaptive behavior. That is, the forcing structure provides self-organized order, which employs only a profoundly restricted ($\sqrt{N}$) number of all potential (2^N) states; the latter, regions of indeterminate activity, comprise the remaining potential states, a vast treasury of the stuff of change, adaptation, and evolution. The forcing structure is the emergent Self of a system, the relativists' and positivists'

[1] Kauffman calls Boolean functions such as AND & OR "*canalyzing Boolean functions*" because each has "the property that it has at least one input having at least one value (1 or 0) which suffices to guarantee that the regulated element assumes a specific value (1 or 0)" ([2], p. 203-4). The EXCLUSIVE OR function, by contrast, is not a canalyzing function, for its output is 1 as long as *only one* of the inputs is 1. "Large, connected forcing structures percolate spontaneously in $K = 2$ networks because a high proportion of the 16 possible Boolean functions of $K = 2$ inputs are canalyzing functions" (p. 205).

"complex whole"; the islands of left-over material are that part of the system in which exist potential alternate states of that Self.

Now that the protocols of systemic self-organization have been established, what role does this order play in adaptive behavior? The coalescence of spontaneous order separates a complex system into distinct morphological regions, forcing structure and isolated islands, the former being spontaneous order itself. In the solid regime, these islands — the "carriers of alternative development decisions via their alternative attractors" ([2], p. 501) — are modular and isolated, and therefore "mutations altering the behavior of one island in useful ways can accumulate without altering the behavior of other islands" (p. 226). It may well be that "adaptation typically progresses through small changes involving a *local* search in the space of possibilities" (p. 33), but for evolution to occur the change cannot remain local. Adaptation is the process by which useful mutations become systemic. In short, there must be some way for the islands to "communicate" their adaptive potentialities to the forcing structure. To understand how this last dynamic works, it is necessary to leave the cozy, idealized simplicity of $K = 2$ Boolean networks.

Chaotic systems are deemed thus because they seemingly move between all possible states at random, and fully orderly systems become locked onto more or less invariant attractors, closed off from their adaptive potential. But in the everyday world, neither order nor chaos holds sway. We are within the regime of order, but chaos infiltrates our every moment. We live in a world which presents novelty at every turn, and we *survive* neither by randomly sampling every possible reaction nor by reacting according to the same pattern no matter what confronts us. There is instead an orderly exploitation of chaos. The possibility of such behavior is the possibility of learning, adapting, evolving. We have already seen that such a balance between chaos and order is characteristic of systems only within a narrow band of initial conditions. Kauffman's experimental studies of *NK* Boolean networks demonstrate the existence of a phase transition from chaos to order, christened "the edge of chaos." This transition regime, the regime of complex adaptivity, is explained by Kauffman thus:

> Orderly dynamics is due to the percolation of a frozen phase containing functionally isolated islands. Conversely the chaotic phase has no percolating frozen clusters. Deep in the frozen, orderly phase, each functionally isolated island can perform its own computations but is unable to communicate with other islands. Conversely in the chaotic phase, orderly computation seems improbable since any slight perturbation will cause damage to spread exponentially. At the margin, normally isolated islands might be in tenuous contact with one another ... The border between order and chaos — the complex regime — is a phase transition where the frozen component is just percolating and the unfrozen region is just breaking into islands. ([2], pp. 221, 234)

With these statements Kauffman reaches the third of the three tiers of his study. On a rugged fitness landscape — the only type that exists in our world — mutation and selection alone are insufficient to the task of progressive adaptation; they work to a point, but inevitably become fixed at a low local optimum. Instead, a more active variety of adaptation is necessary for riding the edge of chaos. Self-organized forcing structures supply an orderly structure within which mutations may occur. The openness of the system to chaotic influence "melts" those walls slightly, allowing the otherwise isolated islands of adaptive potential to "communicate" with one another. To reduce the level of metaphor, at the edge of

chaos, the instability (relative to a system fully in the orderly regime) of the forcing structure allows useful alterations in that structure to link up, while the homeostatic tendency native to these structures conserves the basic state cycle. It is the complex adaptive system's simultaneous potential for entering a vast number of states, and its ability to greatly limit that potential, that enables such systems, poised on the edge of chaos, to exhibit their strongly adaptive behavior in the instance of disturbances affecting one or more of their local features. "Here many mutations cause minor changes and some mutations cause major changes. In a changing environment, this range of responses provides adaptive buffering: If the abiotic or coevolutionary world changes dramatically, large useful changes due to single mutations can be found rapidly; if the world changes only slightly, minor useful changes in behavior lie to hand" ([2], p. 232).

4. Approaching Culture's Complexity

To recap my argument so far: Starting from E. B. Tylor's inaugural definition of culture, anthropologists and sociologists have struggled with what it means for culture (or society) to be a "complex whole." The pursuit of this complex whole has met with severe criticism. For in order to maintain culture's wholism, cultural relativists and positivists have been forced to artificially limit the range of meanings that might attach to cultural symbols or values. Complexity theory too is interested in complex wholes. Moreover, the paradigm of complex adaptive systems may escape the shortcomings of relativist and positivist wholisms, for within this model meaning is not limited by scholarly fiat. Rather, the limitation of meaning is a function of these systems' inner processes. Superabundant meaning is the store of adaptive potential and plays a crucial role in the functioning of complex adaptive systems. Finally, I presented Kauffman's model of the complex adaptive system, and the three tiers of his revised evolutionary theory. First, natural selection is not the sole engine driving evolution, but is complemented by spontaneous order, the property of some systems to severely limit the length of their state cycles and to preserve homeostasis within those cycles. This first stage provides a functional explanation of what it means for something to have an identity, to be a complex whole. Second, we have seen that complex systems tend towards homeostasis as a result of forcing structures, chains of elements connected by canalyzing rules, which are particularly resistant to mutative pressures. Finally, Kauffman's contextualization of Boolean nets within a coevolutionary model leads him to a "terribly important bold hypothesis," namely that "adaptive evolution achieves the kind of complex systems which are able to adapt" ([1], p. 235). For a system to be complex, whole, and adaptive it must necessarily achieve the poised state at the edge of chaos.

Now that we have this rather impressive model from Kauffman, what to do with it? Kauffman's Boolean nets are mathematical idealizations of systemic behaviors, quantifiable, determinate, exact. It goes without saying that similar mathematical-logical models are impossible to generate for many actual cultural and social systems, if not all.

Take, for instance, my study of Buddhism. Buddhism had a long and varied history in ancient India, stretching from the fifth century B.C.E. to the fourteenth C.E. Narrowing this scope, my own research focuses upon a single monastic site founded in Western India during the late fifth century (c. 462-480). Named "Ajanta" after a nearby village, this site is a complex of thirty-one worship halls and monasteries hewn out of a sheer mountain scarp overhanging a river. These Buddhist caves were no mean hovels for impoverished monks.

Rather, the Ajanta caves were religious donations made by members of a royal court. They were stone chambers transformed into grand palaces of religion, adorned with the finest paintings to come from ancient India, as well as exemplary architecture and sculpture. Possessing many epigraphic records as well, Ajanta is unique in India for its wealth of data, rendering it a source for information regarding India's political and economic histories on the one hand, and its culture, ideals, and ideologies, on the other. Indeed, Ajanta holds particular interest precisely because it is one of the few Indian Buddhist locales from which evidence sufficient for a reconstruction of circumstances surrounding its creation is preserved. Lacking such evidence, the multi-leveled consideration of Ajanta's local community as constituent of a complex and dynamic social system is impossible.

Yet, despite Ajanta's scholarly riches, it would be impossible to stipulate and organize into an *NK* network model all the doctrinal, political, economic, familial, psychological, legal, ecological, meteorological, geographical and aesthetic factors consequential for Ajanta's realization. Beyond the sheer complexity of such a project, the necessary data is simply not available. Kauffman describes his Boolean networks as "a caricature," but holds that they are nevertheless "a powerful idealization with which to think about a broad class of continuous nonlinear systems" ([2], p. 188). Is this model useless because I cannot construct — even in caricature — an algorithm for the production of these Buddhist caves that accounts for everything significant at the site? Is the autonomous random *NK* Boolean network not a model at all when it comes to this cultural production, but simply the basis for an analogy?

The answer to these questions depends largely upon one's acceptance or rejection of the complex adaptive systems paradigm itself. If one acknowledges Kauffman's (tentative) claim that he is on track to discovering the "characteristic features so deeply requisite for the capacity to adapt" (p. xiv), and if one acknowledges that these features construct organisms internally "such that they are in the solid regime but near the edge of chaos" (p. 279), then one must acknowledge that the adaptive capabilities of all systems — physical, biological, social, and cultural — result from their being in the solid regime near the edge of chaos. If one considers that this poised state is predicated upon there being a self-organized system, and if one considers that systems self-organize through the production of forcing structures by means of canalyzing rules, then one might inquire into how social or cultural systems self-organize, what constitute the nodes in a social or cultural forcing structure, and what kinds of rules might link these nodes. In short, if one accepts Kauffman's work, one accepts the thesis that a "general law concerning the evolution of *self-constructing* open, far-from-equilibrium systems" (p. 389) is possible. This possibility in turn allows, even requires, one to search for the systemic properties and meta-systemic behaviors predicted by this general law within evolutionary systems that cannot be directly modeled mathematically as complex adaptive systems.

This is not the venue in which to assess the complex adaptive systems paradigm's validity. Instead, acknowledging Kauffman's claims and accepting his work, I will return to the matter of culture for the remainder of my talk. In particular I will attempt to explore culture as a complex adaptive system through Kauffman's model of self-organization, forcing structures, canalyzing rules, and chaos. How can one understand culture as a self-organized complex whole, i.e., a forcing structure organized, or linked, by canalyzing rules that foster homeostasis in the face of environmental chaos, yet also allow for systemic evolution? Of what is this structure comprised? What are the canalyzing rules?

This investigation began with Tylor's characterization of culture as a "complex whole." But now, by way of approach to culture as a complex and adaptive whole, we can take advantage of developments in anthropology that have "narrow[ed] the concept of culture so that it includes less and reveals more" ([5], p. 73). Particularly apropos here is Geertz's presentation of culture as "semiotic":

> ... man is an animal suspended in webs of significance he himself has spun, I take culture to be those webs ([6], p. 5).

Geertz spins a kind of *NK* Boolean web himself, wherein the cultural system is the "ordered system of meaning and symbols, in terms of which social interaction takes place" and the social system is "the pattern of social interaction itself" (p. 144). Culture being the shared symbolic values that connect a random population into a society, one can translate this relationship into Kauffman's terminology thus: culture provides the canalyzing rules that define social self-definition. More specifically, culture's forcing structure is comprised of *N* elements organized into a dynamic system of symbolic values; culture's canalyzing rules are the *K* connections between cultural elements that give rise to coherent societies.

As one might expect, this utilization of the complex adaptive systems paradigm raises more problems than it solves. For although we can translate Geertz's terminology into that of Kauffman, the fidelity of this translation is by no means certain. Culture is a complex whole insofar as its elements are diverse and linked; it is a complex adaptive whole insofar as the symbolic values which comprise it are fluid, open to reinterpretation and reintegration in the event of environmental pressures. Accordingly, to test the applicability of Kauffman's model to culture we must determine how the symbolic values that give identity to a cultural system form a complex systemic whole that remains orderly at the edge of chaos; how culture can serve simultaneously as the basis of social-systemic self-identity and the locus of mutation and systemic evolution; what the properties of culture systems may be that facilitate dynamic self-organization, as do Kauffman's canalyzing Boolean functions.

Geertz himself provides additional insights through which to address these questions. He writes, "so far as culture patterns, that is, systems of or complexes of symbols, are concerned, the generic trait which is of first importance for us here is that they are extrinsic sources of information" ([6], p. 92). In Geertzian terms, cultures are systems of extrinsic and informational symbols. By "extrinsic," Geertz means that cultural symbols "lie outside the boundaries of the individual organism as such in that intersubjective world of common understandings into which all human individuals are born" (p. 92). By "sources of information" he means that "culture patterns provide ... programs for the institution of the social and psychological process which shape public behavior" (p. 92) in much the same way that DNA strands enable the formation of proteins. For Geertz, culture is "semiotic," "extrinsic," and a "source of information." And I would propose our questions about culture as a complex whole may be answered if we can ascertain how these three properties "canalyze" cultural values into a functional whole capable of adaptation. The remainder of this paper will attempt to explore how this mechanism works, exploring each property in turn.

Let us begin with culture as "semiotic." Being semiotic, the "webs of significance" that comprise culture are, in Geertz's words, "interworked systems of construable signs" (p. 14). However, Geertz and his fellow symbolic anthropologists have been notoriously unsystematic in their use of semiological terminology. This circumstance is noted by E. Valentine Daniel, who has attempted to set the discourse aright through appeal to Peircean semiotics. The Peircean sign is an irreducible triad, of the *sign* itself, the *object*, and the *interpretant*:

> Objects may exist in the universe as individual empiricities or existent facts, but they do not become real until and unless they are represented by a sign, which representation is interpreted as such by an interpretant ([7], p. 19).

Indeed, Peirce's understanding of the sign is the crucial foundation of my own analysis. The Peircean sign is suitable as an *N* element within a complex adaptive whole, for such a sign can never have a static meaning. The sign — its own first element — is recursive, leaving open the possibility of a glissade between the sign and its own representations as "sign." Again, the sign is other than itself; for, to be significant, it requires the work of an interpretant, which unites sign and object. Like Geertz's "man," the signified object, too, is suspended in webs of significance. Indeed, Peirce even eliminates this distinction between "man," "object" and "sign" when he stipulates that "the interpretant becom[es] in turn a sign, and so on *ad infinitum*" ([8], p. 58). We draw ever further from the *object* as we draw ever closer to the sign in its totality, its complex locus of meaning.

The second property of culture, according to Geertz, is that it is "extrinsic": "Culture is public because meaning is" ([6], p. 12). And we have just found that semiotic meaning is public because the sign cannot exist apart from the work of interpretation, which, of course, requires there be a worker.

To explore this aspect of culture, I will once again hearken to my work at Ajanta. Culture's publicity is crucial to my study of the Ajanta caves, for the evidence these caves provide is irreducibly public. My broader study of Buddhist culture can undertake the analytic challenges it sets for itself only if the full range of these caves' material remains — paintings, sculptures, inscriptions, architectural plans, as well as minutiae, such as door-fittings, chiseling styles, plaster materials, and numerous other details — are viewed as signs of signs. Functioning as signs of an understanding, a set of values, a structure of meaning, what have you, shared by Ajanta's community, the painting of a distressed princess and a sculpted door guardian's serene smile are religious artifacts alongside the site's monolithic icons and hagiographic renderings.

To clarify what is at stake here, I must explain a bit of Buddhism. Properly speaking, a "Buddhist" is someone who performs a ritual in which he "takes refuge in the Three Jewels." These Jewels are the *Buddha* (the religious ideal), the *Dharma* (the universal Truth), and the *Sangha* (the Buddhist community). As a famed Tibetan teacher put it, "one does not enter the ranks of Buddhists until one has gone for refuge" ([9], p. 49). The Three Jewels, true to their metaphor, are gems whose many facets (doctrinal, ideological, institutional, mythical, practical) glint variously in the light of inquiry. Although these Jewels' faces can never be wholly illumined — indeed, there would be no magic in a gem evenly illuminated throughout — all that is Buddhist can finally be reduced to a facet of one of the Three Jewels. To say that the Ajanta caves were Buddhist, therefore, is to say that they contained representations of the Three Jewels. As this site's patrons represented the Three Jewels, communicating their conceptions of what it meant to be a Buddhist, these patrons constructed their own identities as Buddhists. Similarly, we can speak of Buddhist culture as predicated of the Three Jewels. Bringing in the element of Kauffman's Boolean nets, we might say that Buddha, Dharma, and Sangha are the *N* elements that form the forcing structure of a Buddhist-order. For people who are Buddhists, these Three Jewels force se-

lectivity upon the interpretation of environmental information, and delimit the range of potential meaning. A Buddhist culture "spontaneously" self-arises as individuals enter the Buddhist community through the taking of refuge in the Three Jewels. Significantly, although the formula by which one becomes a Buddhist has the form of a personal confession of faith — I go for refuge to the Buddha, I go for refuge to the Dharma, I go for refuge to the Sangha — the rite's universality renders it less a *credo*, a declaration of personal beliefs, than an illocutionary enactment thereof.

In brief, the issue in the study of Ajanta's Buddhist culture is *not* of the private interior of religious belief. Indian Buddhism possessed nothing comparable to a genre of confessional literature; the intimate motivations these long-dead individuals had for undertaking religious action are now all but lost. The Buddhist identity (the cultural Self, the forcing structure) to be found in the cave monasteries' realizations of the Three Jewels is that of Buddhists as public actors, religious actors whose personality was articulated in artifacts rather than articles of belief. This distinction is borrowed in part from one the anthropologist Roy Rappaport draws between "belief" and "acceptance." Belief and acceptance are two modes of personal involvement in matters religious, but, as Rappaport stipulates, "Belief [is] ... some sort of inward state knowable subjectively, if at all. Acceptance, in contrast, is not a private state but a *public act*, visible to both the witnesses and the performer himself" ([10], p. 194) This is to say, by participating in a public religious act "the performer accepts, and indicates to himself and others that he accepts, whatever is encoded in the canon of the liturgical order in which he is participating" (p. 193, fully italicized in the original). The information *accepted*, the canon "encoded" in the liturgical order, is nothing other than the public sign. The analytical utility of Rappaport's distinction lies in the following corollary: no matter what one's personal motivation for involving oneself in a public religious act — whether it is because one privately believes in the efficacy, canons, or ideals encoded therein, or because one is simply playing to community expectations — the artifacts left by such participation can be treated as indices of a total religious fact.

Third, culture coalesces into a complex adaptive whole because the public signs that comprise its forcing structure are also "sources of information." Kauffman located adaptive behavior at the edge of chaos because in that regime individuated islands of adaptive potential are able to "communicate" with one another and to coordinate and accelerate their adaptive accretions. Evolution is a function of the increase in mutual information. This view — adaptive behavior is the functional exercise of knowledge — is not unique to Kauffman, who reflects that "complex living systems must 'know' their worlds" ([2], p. 232). Indeed, Christopher Langton takes this understanding one step further, establishing information processing as the hallmark of a system deserving of the epithet "living":

> The most salient feature that distinguishes living organisms is that their behavior is clearly based on complex dynamics of information. In living systems, information processing has somehow gained the upper hand over the dynamics of energy that dominates the behavior of most non-living systems ([11], p. 42).

The lower edge of such knowledge is found in the chemical signals through which an *Escherichia coli* bacterium negotiates its world, recognizing nourishment to maintain its own metabolism and reproduce. At a higher level, I can attest by personal observation that Maharashtrian langurs dearly love bananas and oranges, but will not even touch a tomato, a *New World* fruit. Insofar as tomatoes are not physically hazardous to the langur, we would speak of tomato-eating langurs as displaying adaptive behavior conducive to greater fitness

(unless — to point out the multi-leveled problems of coevolution — Indian tomato growers are a particularly bellicose breed, more prone to kill langurs than simply scare them away); we could describe such behavior as indicative of these langurs' fuller knowledge of their world. Adaptive behavior represents an increase in environmental knowledge, be that environment natural or cultural.

On the level of evolutionary development attained by human communities, culture is the source of information through which the world is modeled and made socially and psychologically habitable. This information is public and semiotic. It is also pragmatic, and therein lies its potential for fostering adaptive behavior. Adaptation is possible only when increased knowledge can be shared across the system, that is to say when local adjustments in the self-organized forcing structure are able to occasion beneficial alterations in systemic behavior. On the level of culture, this sharing of knowledge takes place in terms of *signs*, i.e., public meanings, and is enabled by the self-realization inherent to *acceptance*.

In light of Rappaport's *acceptance*, cultural knowledge is a species of self-knowledge wherein the biological self contacts its own publicity: an individual's participation in religious activities signals to witnesses and *the performer himself* his acceptance of the performed liturgy's encoded canons. Like the Piercean sign, this self-conscious actor is both recursive and other: the biological self participates in cultural meaning (manipulates signs) through the public self (interpretant). Such self-knowledge is called "pragmatic" because the public self is itself known through its interpretation of signs, which are nothing other than its public actions. This pragmatic knowledge, in turn, is the source of adaptive potential because the infinitude of semiological interpretations based on culture-supplied information renders self-knowing an open-ended process. Identity is the Janus-face of acceptance, which is nothing other than the irreducible publicity of action. The relentless search for identity is the engine driving the work of adaptation, for the biological self can never quite become adequate to its social significance when that significance is ever heaving and deforming.

Culture works to bind a community in its webs of significance as it supplies the shared signs through which a community knows its world and as it fosters a communally shared interpretation thereof. But the study of culture as a semiotic enterprise works by reading a community's objects, its artifacts, as signs implicated in an indefinite web of interpretations. For the members of an ancient Indian Buddhist community, a knowledge of themselves *as Buddhists* involved an integration realized pragmatically in action. We designate this act of interpretation by other well-known terms: excavation and decoration. Inputs affecting artisans and inhabitants at Buddhist cave sites might have included the number and status of new patrons and the fluctuating amount current patrons were able willing to devote to their projects; inputs affecting potential or actual patrons might have included a desire to raise one's personal prestige within the court, a powerful religious experience, a death in the family. Outputs are measured in terms of the chosen iconographies, the intended iconologies, decorative schemes, donative formulae used, epithets adopted. Signs all, meaningful as public and shared displays of knowledge. Through these acts, the public selves of these ancient Buddhists have themselves became objects, which in our modern academic environment are signs for cultural analysis. Indeed, all three elements of the triadic sign are present equally in my study of Buddhist culture at Ajanta: the *object* is the self-understanding of Ajanta's community — which is nothing other than its complex behaviors — represented in the Ajanta caves *as sign;* the interpretant being this very paper I read to you today.

5. Conclusion

To sum up the final section: following Geertz, I have presented "symbolic values" as the building blocks of cultural systems. And I have suggested that by viewing these symbolic values under the Piercean rubric one can comprehend how they coalesce into a system that is simultaneously homeostatic and capable of change. Piercean signs have no absolute values determined within an idealized chain of signification; participants in a culture do not merely reflect fixed cultural values through their actions. Rather, the values cultural signs embody are fluid, for the members of a culture interpret their own experiences through these signs, but that very act of interpretation alters the signs' values, allowing them to remain meaningful within a dynamic social environment. The range of any sign's meaning is potentially infinite. Yet as meaning is pragmatically realized in action this range is vastly reduced to a tiny sub volume of its potential, allowing for stability on the edge of chaos.

To be sure, this initial attempt to present culture as a complex adaptive whole is sketchy and incomplete. I rely upon Geertz's characterizations of culture. Yet Geertz's work has come under severe criticism, if only because he does not explain what he means by the "meaning" inherent in cultural values [12, 7, 1]. Though Geertz's prose works neatly into my discourse, any amplification of this paper would require that I address Geertz's work in order to clarify how my presentation of culture as a complex whole differs from his own. Indeed, there may even be more useful accounts of cultural systematics that I have ignored. Similarly, I have relied heavily upon the work of Stuart A. Kauffman, but only touched upon a sampling from his monograph [13]. The study of complex adaptive systems of course far exceeds Kauffman's work. In this brief study I have possibly ignored genetic algorithms [14] other than *NK* Boolean nets, explanations for systemic self-organization other than forcing structures brought about by canalyzing rules, or other essential properties of complex adaptive systems that could be of even greater value for the study of culture than those I did present. At this preliminary stage of my investigation, I hope to have demonstrated that if the complex adaptive system at the edge of chaos is accepted as a paradigm for evolutionary systems then the scholarship dedicated to these systems can offer models through which to understand the workings of the social world.

Acknowledgments

I wish to thank Professor Luis O. Gómez, without whose insights and skepticism this paper would not have been written.

References

[1] C. Herbert, Culture and Anomie. University of Chicago Press, Chicago, 1991.
[2] S. Kauffman, The Origins of Order. Oxford University Press, Oxford, 1993.
[3] M. Mauss, The Gift, translated by Ian Cunnison. Norton, New York, 1967.
[4] E. Nagel and J. R. Newman, Gödel's Proof. New York University Press, New York, 1958.
[5] R. Keesing, Theories of Culture, *Annual Review of Anthropology* **3** 73-98.
[6] C. Geertz, The Interpretation of Cultures. Harper, New York, 1973.

[7] E.V. Daniel, Fluid Signs: Being a Person the Tamil Way. University of California Press, Berkeley, 1984.
[8] J. Ransdell, On Pierce's Conception of the Iconic Sign. In: P. Boussiac et. al. (Eds.), Iconicity, Stauffenburg Verlag, Tübingen, 1986.
[9] M.M. Singh (Ed.), Sulekha of Sakya Pandita (skyes-bu-dam-pa-rnams-spring-wa'i-ge-bzhugs-so), Bihar Research Society, Patna, 1971.
[10] R.A. Rappaport, Ecology, Meaning, and Religion. North Atlantic Books, Berkeley, 1979.
[11] C.G. Langton, Life at the Edge of Chaos. In: C. G. Langton et. al. (Eds.), Artificial Life II. Santa Fe Institute Studies in The Sciences of Complexity Proceedings, Vol. 10. Redwood City: Addison-Wesley, Redwood City, 1992.
[12] Talal Asad, Genealogies of Religion. Johns Hopkins University Press, Baltimore, 1993.
[13] S.A. Kauffman, Antichaos and Adaptation, *Scientific American* **265** (1991) 78-84.
[14] J. Holland, Complex Adaptive Systems, *Daedalus* **121** (1992) 17-30.