UNDERSTANDING COMPLEXITY
IN THE PREHISTORIC SOUTHWEST

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The Santa Fe Institute (SFI) is a multidisciplinary center dedicated to the understanding of simplicity and complexity. A large part of its work is devoted to the study of the similarities and differences among many kinds of complex adaptive systems (CAS). A complex adaptive system is a system that learns or evolves by utilizing acquired information. It identifies perceived regularities in the data stream reaching it and compresses those regularities into concise packages that are often called schemata. A schema, supplemented by further information, leads to a description of the outside world or to predictions about it or to behavior of the complex adaptive system in its interaction with that world.

In biological evolution, the genome of an organism is a schema. In the scientific enterprise, a theory is a schema. In the evolution of a society, such things as laws, traditions, kinship rules, and myths constitute schemata—they are sometimes described as cultural DNA. Schemata are subject to variation and the different variants are in competition with one another. The descriptions or predictions provided by a schema can be tested by comparison with further inputs of data. Similarly, behavior prescribed by a schema is tested by its consequences. Thus selection pressures are created that feed back to the competition among schemata. Some schemata are rewarded by survival or at least by promotion, while others are suppressed or demoted. The selection pressures in biological evolution favor a genome that leads...
to survival and to successful reproduction on the part of the organism or its close relatives. Scientific selection pressures favor a consistent body of theory that leads to explanation of observations and successful predictions of further observations. In cultural evolution, schemata will be favored that, among other things, offer advantages in responding to changing social and environmental conditions.

Adaptation to changing circumstances, say on the part of a society, can take place on at least three levels, with three different time scales: (1) The society can adapt to certain changes by following the rules of a particular schema for behavior. In response to a drought, a village may be moved to a higher elevation where more moisture is available. Or the villagers may perform a ceremony believed to enhance the probability of rain. Or both. (2) A schema for the behavior of the society can be exchanged for a different one. A new religion might be introduced with a different way of praying for rain. New agricultural methods might be adopted. (3) The society may disappear, carrying its unsuccessful schemata into extinction with it, while other societies, with other schemata, may survive.

In many cases a CAS is composed of smaller complex adaptive systems interacting with one another. Such a composite CAS is said to consist of adaptive agents. Those agents are typically engaged in constructing schemata for describing and predicting one another's behavior. A society is a composite CAS in which the agents can be taken to be individuals or else households or larger social units. Other examples are ecological communities, composed of individual organisms of many species, and financial markets, composed of individuals or firms as investors.

A particularly instructive kind of complex adaptive system is a computer programed to evolve strategies for playing a game. If playing the game optimally were a solved problem, as in tic-tac-toe, then such a computer would soon reach a kind of equilibrium by finding the optimal strategy. However, in a game like chess, where the optimal strategy has not yet been discovered, the computer operates far from any equilibrium, in a continuing search among possible strategies. Complex adaptive systems usually find themselves far from perfect adaptation in this sense. That is true to an even greater extent when the external conditions keep changing. Thus a CAS is often highly dynamic.

SFI operates by means of multidisciplinary research teams of affiliated researchers drawn from a diverse group of disciplines, academic institutions, research centers, and research-oriented corporations. The research problem is the cohesive element binding these scientists together; they do not share a particular research method or ensemble of theories. The external faculty along with additional invited scholars interact largely through workshops focused on specific topics, by means of a graduate summer school in the sciences of complexity, and by research networks linked through electronic communication.

The form of organization at SFI, together with the method of carrying out research, is nearly unique. So too is the manner in which questions are addressed. SFI researchers believe that different methods of inquiry are most effective if they are used in combination with one another, rather than in opposition. For instance, while it is carrying on major factoring, on the ability to remain in grand schematics of thinking and examining.

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...listed results research cohesive research al invited means of networks...tying out addressed...ve if they instance,...while it is common to give lip service to the concept that critical and creative thinking are complementary methods of inquiry, these approaches are often treated, in carrying out actual research, as if they were in conflict. Critical thinking ability is a major factor in the advancement of knowledge. It is the capacity to evaluate ideas, to probe weaknesses in logic, to judge concepts, and to test ideas. Creative thinking, on the other hand, is crucial for the development of new hypotheses and the ability to find and understand relationships among phenomena. Some researchers remain in the critical thinking stage, and there are those creative thinkers whose grand schemes cannot stand up to critical scrutiny. SFI scientists try to blend elements of critical and creative thinking in the way they address their problems. The researchers understand that a single individual need not exc: in both types of thinking skills but that the two abilities must nevertheless be used in order to examine successfully large questions in any scientific domain.

The SFI philosophy similarly holds that generalizing and specializing traditions in science are complementary and not contradictory, and that it is important to adopt a generalizing approach while paying careful attention to detail. Since the behavior of a nonlinear complex system cannot be described in terms of the sum of the behaviors of its parts, an attempt must be made to comprehend the whole situation, even crudely if necessary, while also examining the individual elements with care. The interplay between the specialist who understands the details and the generalist (usually but not always a different person) who can view the whole picture is a vital part of understanding complex systems.

The characteristics that epitomize SFI research can profitably be applied to archaeological problems because cultures are complex adaptive systems. When referring to culture, archaeologists traditionally use both the terms system and complexity. Despite criticisms of the appropriateness of the use of the systems concept for culture and problems involving use of the term complex in specific situations, recent advances in understanding how systems are organized and evolve and a broader definition of complexity enhance the usefulness of the terms for understanding cultural systems.

Most archaeologists and other anthropologists use the word “complex” in two different ways. It can be used in the general sense of “complicated” or “intricate” or else in a more technical sense, referring to societies that are hierarchically organized, usually with features of organization that are not found in egalitarian societies such as bands or tribes. In the second sense, societies have been described as complex when there are many different roles, often associated with different status, that distinguish individuals and when criteria other than age, sex, and ability are applied in filling positions of power or authority.

Two of us have commented as follows on the relation between “effective complexity” as used in some of the scientific work at SFI and the technical use of the term “complexity” or “social complexity” in archaeology:
Complexity is not easy to define. In order to capture the intuitive ideas that most of us have of what complexity means, several different quantities would probably have to be introduced. It turns out, however, that in most scientific usage and in much ordinary discourse what is meant by the complexity of a system being observed is, more or less, the length of the description given by the observer of the regularities of the system. This is obviously a subjective or context-dependent—even a behavioral-definition, but no comparable objective definition has ever been found. Probably there is none. Granted the subjectivity of the definition, it is still necessary to provide a number of comments and qualifications before the concept can be used.

For one thing, the length of an ostensive description is no good; it is just as easy to point to a complicated system as to a simple one. Likewise, since a short nickname could be given to any system, the description should be in a language previously agreed upon with a correspondent (and a distant correspondent at that, to eliminate the possibility of pointing).

Not only the language, but also the knowledge and understanding of the world that are shared by the observer and the correspondent may significantly affect the length of message required for the description. Just as important is the level of detail achieved in the description—what is known in physical science as the “coarse graining.”

Given the coarse graining, the language, and the assumed level of knowledge and understanding, the description should be as concise as possible. The length could, of course, be artificially inflated by the use of unnecessary verbiage or just by repeating things that could be said only once.

So far, then, we are discussing a definition of complexity based on (1) the length of a concise description, (2) to a distant correspondent, (3) using language previously agreed upon, (4) of the regularities of an observed system, (5) given the coarse graining that is applied, and (6) the knowledge and understanding of the world shared by the observer and the correspondent. But this definition still leaves the notion of regularities to be examined. What does it mean to separate regularities from random details?

For a finite stream of data, there is no rigorous way to distinguish a system’s regular features from those that are attributed to chance. For an infinite stream, the situation is more hopeful. If possible, we should therefore be dealing with a very large body of data. As the amount of coarse-grained information increases, so does the meaningfulness of extracting regularities, since a regular pattern will be more likely to recur frequently enough to set it off from incidental features.

We can see how the foregoing observations apply in the description of a prehistoric society, with emphasis on its social structure. Evidently, complexity does not depend on the length of a message that merely designates
sites or names a branch or phase of a particular ruin. We also see that the concentration on social complexity means that the coarse graining will ignore features of the remains that do not appear to bear importantly on social structure. The language for discussing that structure is fairly standard these days and is heavily influenced by certain theories, of various degrees of plausibility and usefulness, of what is considered to be a typical sequence of stages of societal development. The regularities that are actually identified are similarly constrained by the limitations of current theories. Finally, it is clear that the likelihood of recognizing patterns of social structure is increased if there is an abundance of material.

In the light of these rather obvious general remarks, we can see that the social complexity assigned by an archaeologist to a prehistoric culture really does typically relate to the length of the concise description of regularities—the various social roles, the patterns of residence, the distribution and architecture of public buildings, the arts and crafts, the technology, the utilization of plant and animal species, the relations with other cultures, and so forth—as well as to the “variety of mechanisms for organizing these into a coherent, functioning whole.”

Sometimes, societies are described as more or less complex merely according to how they are thought to fit into a particular presumed sequence of evolutionary stages. Such an interpretation of the extent that it agrees with the more general interpretation given here. Fortunately, it often does agree, and the concept of complexity as a measure of the evolutionary status of a society continues to have heuristic potential despite recent criticism.

There is no question that after the adoption of agriculture, societies tend to evolve into more complex entities. The intertwined relationships among agricultural intensification, population growth, political integration, and social role diversity are major aspects of the processes of cultural evolution. Usually those changes are associated with an increase in social inequality, and it is an interesting question whether that effect was less blatant in parts of the Southwest than in societies at comparable stages of evolution elsewhere in the world, as has sometimes been claimed.

—From Gumерman and Gell-Mann

(references within this quoted material have been changed to reflect the reference list for this chapter)

Many archaeologists today find that the use of traditional categories such as simple vs. complex, does not promote understanding of how cultures work or develop and evolve over time. Rather than trying to maintain the categories, recent approaches examine the trajectories of organizational dimensions such as
community or site size, numbers of levels in site size hierarchies, the area encompassed by exchange networks, evidence of craft specialization, etc. Much of this research is concerned with organizational properties.16,17,19

The distinction between specialization and generalization in research orientation, in the more common meanings of detailed versus broad, has also been a major theme in archaeology, although it is not much discussed.14 While emphasis in southwestern archaeology in the last few decades has been on specialization, a number of generalizing studies have attempted to bring the detail of more specialized efforts into broader interpretations for larger sections of the Southwest, even the region as a whole. But how can archaeologists use the richness of detail and uniqueness of the culture history of scores of specific locales in the Southwest to understand general notions about human societies?

One answer lies in enhancing the kind of structure for investigating research problems advocated by SFI and traditionally used by archaeologists—bringing groups of people together to work on a problem. Archaeologists have always used group efforts. Until the 1960s, however, while field work, analysis, and write up were accomplished by groups of people with diverse specialties, usually only one individual was responsible for obtaining funding, directing the intellectual thrust of the project, and supervising excavation, analysis, and interpretation—a structure called the “lone scholar” approach.13 Archaeologists operating under this model of scientific enterprise successfully laid the foundations for the understanding of the past that we have today. In the 1960s and 1970s, however, it became necessary to test other organizational models because the size and number of projects in contract archaeology required more participatory team efforts.

The change, however, was not all due to contract work. One of the first problem-oriented group efforts was the Southwest Anthropological Research Group (SARG). In part, SARG was a response to Streuver’s call for research that would transcend the “lone scholar” approach that was not adequate to address problems of cultural interaction and culture change. SARG was a concerted group effort to collect data in a comparable way, to try to understand why people distributed themselves across the landscape the way they did.12 The exercise was notable for two reasons. First, it was a coordinated group effort in what was then an atmosphere of divisiveness in southwestern archaeology. SARG engendered tremendous intellectual excitement because it involved many scholars of different intellectual persuasions who were willing to share unpublished data, and engage in open intellectual debate. Second, SARG was distinctive in that it met to pose and address problems, rather than to present results. It is unfortunately characteristic of archaeologists, worldwide, that we seldom get together to discuss problems and to formulate and prioritize research concerns.6 Archaeologists tend towards individualism in conducting and reporting research. Even the newly founded biannual Southwest Symposium and advanced seminars at the School of American Research usually consist of pre-prepared single-author papers with introductory and synthesizing commentary. These formats hinder insights that can be cooperatively derived. SARG was conceived as an antidote to individualism.

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The increasing sense of the commonality of cultural processes that operated regionally, cutting across the major southwestern traditions was heightened by an advanced seminar, "Dynamics of Southwest Prehistory," held at the School of American Research in 1983. While the structure of the seminar emphasized subregions, such as the San Juan and Upper Rio Grande, the seminar participants named a number of "hinge points" that were characterized by common processes. At about the same time, in 1984, the founding of the Santa Fe Institute and the involvement of Murray Gell-Mann, Robert McCormick Adams, and Douglas W. Schwartz in both SAR and SFI led to the fortuitous coincidence of the renewed interest in viewing the prehistoric Southwest as a single entity while recognizing the great diversity within the region.

A few years thereafter two seminars were held. Jonathan Haas, then of the School of American Research (now at the Field Museum of Natural History), along with Gell-Mann and George Gunerman, planned the long-term effort and then, with the advice of many archaeologists, a structure for the meetings gradually evolved that resulted in the two meetings. The first meeting was an advanced seminar titled "The Organization and Evolution of Prehistoric Southwestern Society" convened in September, 1989, at the School of American Research. Its goals were to examine the pan-southwestern themes and processes (some that resulted in increasing complexity) to attempt to understand the linkages that integrated the various themes and processes, and to lay a basic foundation of knowledge about southwestern archaeology. The advanced seminar was planned to set the stage for the more interdisciplinary workshop at SFI.

For five days in October, 1990, 27 archaeologists, ethnologists, biological anthropologists, and complex system theorists in biology, computer science, and physics met at the Santa Fe Institute to consider the archaeology of the Southwest. Supported by SFI, SAR, and private donors, the workshop, "Organization and Evolution of Southwestern Prehistoric Societies," was devoted to studying and attempting to explain the evolution of complexity in the Southwest. This volume is a result of that workshop.

Since the nature of archaeological data and reasoning is not generally understood outside the discipline, a day-long field trip prior to the conference was organized by Rolf Sinclair of the National Science Foundation. Stephen Lekson, then of the Museum of New Mexico (and now at Crow Canyon Research Center), led a group of workshop participants to archaeological sites near Santa Fe that represent various prehistoric eras and exemplify interpretive quandaries. General overviews of the history and goals of the workshop were given by Gunerman, complex adaptive systems by Gell-Mann, southwestern prehistory by Lekson, cultural evolution by archaeologist Joseph Tainter (U.S. Forest Service), and problems in modeling prehistoric population dynamics by archaeologists Ben Nelson (SUNY Buffalo), Keith Kintigh (Arizona State University), and Timothy Kohler (Washington State University).

Participants were divided into working sessions on a variety of topics of concern in contemporary archaeology such as the nature of explanation in archaeology,
historical processes, environmental and evolutionary modeling, systems modeling, and environment, demography, and health. For each topic, an anthropologist was asked to write a 10- to 15-page draft platform statement. These are very general papers, without specific reference to the Southwest, meant to introduce the general subject to nonanthropologists. They are published in this volume as position papers. The position papers were distributed to all the participants a month before the workshop. In addition, each participant was given a copy of the draft papers presented at the SAR seminar and the nonarchaeologists a reading list of general overviews of Southwest prehistory.

The goal of the Explanation in Archaeology group was to examine how archaeologists in the Southwest structure their research and to suggest ways in which we might do better. The group affirmed the method of science as appropriate for archaeological inquiry, noting the general success of ecological approaches but also recognizing some of its shortcomings. The group examined both the process of archaeological research and the sociology of archaeology including how ideas are rewarded. For example, novelty is encouraged in tenure evaluations while testing existing ideas and using extant data sets are discouraged. The group offers a number of suggestions. These include ways in which more attention might be focused on selecting problems for research, working toward more robust methods of confirmation, promoting what they call a comparative archaeology that would develop a large cross-cultural data base of archaeological information for comparative research, rewarding joint-authorship of publications and encouraging journals to permit footnotes for more complete documentation.

The Historical Processes working group attempted to take historical factors into consideration in understanding culture change and stability. They were concerned with how the existing form of a society changes the manner in which it can adapt, or not adapt, to changing conditions. They focused on characteristics intrinsic to the society which shaped change and stability and to the effect of interaction with other cultures. They argue that all histories are constructed and that there are many possible constructions. They do present a history of development of societies in the Southwest, and in acknowledgment of the multiplicidy of histories and voices, they encouraged other workshop participants to comment on their history in footnotes that they include in their chapter.

The Environmental and Evolutionary Modeling group used rugged fitness landscape models which are based on the concept of coupling, so that a change in the fitness of one system affects the fitness of other systems on the landscape. This concept may help explain the overall trajectory of increasing population despite the series of abandonments. A pattern common in the prehistoric Southwest is that of sequential subregional abandonment. For example, the Chaco Canyon and Virgin River regions were abandoned in the late A.D. 1100s, Mesa Verde in the late 1200s, and the Middle Little Colorado River area in the 1400s. Despite these, the overall temporal trajectory of population growth was positive. The working group suggests that some prehistoric settlement relocations may have been to increasingly
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stable environmental contexts where deformation of the fitness landscape was more difficult.

Another group examined the topic of demography and health, looking at the close articulation between political centralization, cooperative networks, demography, and health. They were able to evaluate several different models that have been proposed to explain various instances of southwestern cultural development in relation to population growth or decline and general health characteristics. The models are truly systemic including such components as birth spacing, maternal health, and so on.

Another working group examined how increases or decreases in the complexity of regional systems of exchange and sociopolitical alliances might be modeled using Holland's Genetic Algorithm, as modified by workshop participant Robert Reynolds (Wayne State University). The Genetic Algorithm is based on a Darwinian paradigm of fitness modified to include learning. Using surrogate measures to monitor dimensions of demographic, economic, social, and political behavior, the working group investigated the potential of a model generated from the Genetic Algorithm to reproduce systems of comparable complexity to those known archaeologically. Efforts such as this one will eventually allow us to specify the ways in which systems of human behavior mirror or depart from the behavior of other complex adaptive systems.

Archaeologists have long been consumers of ideas (e.g., uniformitarianism, gradualist evolution, optimum foraging models, taphonomic processes) and techniques (e.g., radiocarbon dating, playnology) from other disciplines. Unfortunately, sometimes we may adopt theories, concepts, and methods without fully understanding them in their original context, therefore running the risk of using them inappropriately or as simple heuristic devices (e.g., positive and negative feedback). Yet, when we ask how successful are the approaches advocated by SFI and whether or not we have done any more than show trends in Southwest prehistory, we see the integration of different perspectives as beneficial for everyone. The key seems to have been to bring together, in small groups, those with different talents and different data since those scholars who see relationships more often than boundaries.

Sometimes, archaeologists may adopt theories and concepts far too rigidly, making them more static than they should. It is for this reason, for example, that some archaeologists have made formal pronouncements about evolution that seem misguided to evolutionary biologists. At SFI, theoreticians in biological evolution and demography offer suggestions and alternative hypotheses to understand processes they are unsure about. Discovering that things we thought we knew about evolutionary biology are imperfectly understood by evolutionary biologists was a revelation. The nonarchaeologists provided the exceedingly rich and variegated detail about their disciplines that is essential for archaeologists to understand if we are to draw meaningful lessons from their data and useful metaphors from their theories when they are appropriately applied to past cultural behavior.

An important lesson from the experience is the futility of the proponents of rigid points of view, those advocates who do not allow for any flexibility. Cordell in her
position paper for the workshop listed a dozen or so philosophical flags under which some archaeologists march today. If these theoretical perspectives provide flexible guides for research direction, that is one thing. If they are adopted and applied with little flexibility, they are almost certainly wrong. Understanding something as fragmentary and as complex as past cultural systems requires the integration of different points of view—a harmony created by cooperative efforts, the cultivation of creative as well as critical thinking skills, and the application of new analytical and modeling techniques.

We are fully aware that these suggestions for restructuring archaeological research will not resolve all of our difficulties. But one of the participants in the SFI workshop, a nonarchaeologist, remarked on our tentativeness and lack of willingness to espouse partially formulated ideas and to take risks. What have we got to lose?

ACKNOWLEDGMENTS

This volume is the result of a multi-year effort on the part of many researchers—archaeologists and non-archaeologists alike. Both the workshop and the volume is truly a cooperative effort as the large number of multi-authored papers attest. The synergism resulting from the interaction of enthusiastic and knowledgeable researchers can be appreciated by the range and the high quality of the papers in this volume. We are grateful to all of the participants.

The staff of SFI, especially Ronda Butler-Villa, Ginger Richardson, Andi Sutherland, and Della Ulbarri provided not only the necessary support for the success of endeavors of this kind, but did so with an efficiency and friendliness that greatly enhanced our experience. All of the participants express their gratitude.

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