

Evolutionary Theory in Archaeological Explanation

*C. Michael Barton & G.A. Clark
Arizona State University*

ABSTRACT

In spite of the the fact that archaeology embodies the study of change, it is only within the last few years that neo-Darwinian theory has begun to have an impact on archaeological explanation. This lack of acceptance of neo-Darwinian theory in archaeology is in part the result of a long history of archaeologists misunderstanding the processes and expectations of evolutionary theory. This volume attempts to illustrate the applicability of neo-Darwinian theory in archaeology by compiling studies that use this theoretical basis to resolve archaeological problems at varying degrees of temporal depth, at varying scales of social complexity, and employing varying methodologies. Although a broad range of topics are covered in this volume, a number of issues remain to be addressed, including: links between evolutionary units and archaeological explanation; processes involved with the origin of behavioral variability; processes involved with the transmission of behavior; evaluating behavioral fitness; and the role of ‘non-Darwinian’ processes in behavioral change.

If I were to give an award for the single best idea anyone has ever had, I'd give it to Darwin...In a single stroke, the idea of evolution by natural selection unifies the realm of life, meaning, and purpose with the realm of space and time, cause and effect, mechanism and physical law...[N]ot only does Darwin's dangerous idea apply to us directly and at many levels, but the proper application of Darwinian thinking to human issues...illuminates them in ways that have always eluded the traditional approaches, recasting ancient problems and pointing to their solutions.

(Dennett 1995: 21, 23)

Theoretically (in both the scientific and colloquial meaning of the word) archaeology is a field focused on change. From its beginnings as a scholarly discipline in the early years of the last century, archaeology has played an important role in the shift in western thought from perceiving the world as unchanging—designed by and maintained by the constant hand of the divine watchmaker—to a dynamic place where nature makes itself and the only thing certain is change (Eiseley 1958). In fact, the realization of the pervasiveness of change in human cultural systems led 19th century archaeological theoreticians to postulate that all human societies inevitably progressed through a series of stages; only when something went terribly wrong did a society become stalled and fail to change. Change was taken as a given. In the

climate of the industrial revolution, the root cause of change was seen as the innate human drive to improve—obvious in the growing cities, faster ships and trains, more productive factories, and the Horatio Algers of the world (see also Chapter 2).

Biologists did not have such easy explanations for an equally dynamic natural world. Although Lamarck and others proposed innate drives to explain biological change, they met with less widespread acceptance. (An innate drive for increasing neck length wasn't too difficult to attribute to a 'proto-giraffe', but imagining an analogous drive for blue-green algae stretched the imagination too much for many.) Fortunately, Charles Darwin and Alfred Russel Wallace proposed an alternative explanation of why and how life changes. Darwinian

evolutionary theory transformed natural philosophy into scientific biology.

Progressivist social theory was less successful in this regard. By the early 20th century, it was apparent that it was inadequate to explain much of the recently discovered human behavioral diversity, and was abandoned by anthropologists and archaeologists. This left a theoretical vacuum in archaeology that has been filled only slowly and recently (see Chapter 2). Only with the calls of the 'New Archaeology' of the 1960s for a more scientific archaeology, with 'covering laws', did the discipline again seriously consider accounting for change rather than simply documenting it. Although most of the efforts at discovering general laws met with varying degrees of failure, some began to reconsider the ability of Darwinian evolutionary theory to explain change and the language of evolutionary biology began to creep into the archaeological vocabulary.

In most cases only selected aspects (the concept of adaptation, for example) were applied to human societies, often in loose or even inappropriate ways. In the 1970s a few individuals, Robert Dunnell and David Rindos among the most notable, began to call for more inclusive and explicit use of Darwinian evolutionary theory in the explanation of behavioral change (O'Brien 1996). Although initially strongly criticized by many as inappropriate for explaining 'culture' (e.g., see Rindos 1980 and commentary), the explanatory power of Darwinian theory has proven increasingly attractive to archaeologists attempting to take a scientific approach to past human societies and social change, and small but growing number of archaeologists began to echo this call for expanding Darwinian theory to human social systems (e.g., O'Brien & Holland 1990, 1992; Leonard & Jones 1987; see also Teltser 1995a).

By the early 1990s, it was apparent to us that neo-Darwinian evolutionary processes were increasingly employed to account for change in anglophone archaeology. Nevertheless, the history of evolutionary thought in archaeology—including the excesses of 19th century social Darwinists, the misapplication of Spencerian evolutionary theory, the failure of unilineal progressivist schemes, and the problems with recent sociobiological approaches—led many in the discipline to be wary of explicit ties to 'evolution' of any kind. This has retarded overt discussions of how Darwinian theory can be extended from biology to behavior and resulted in many cases in which evolutionary concepts have been misconstrued and misapplied (see O'Brien & Holland 1992, Rindos 1989).

In 1994 we organized a symposium at the Society for American Archaeology meetings to recognize the strong current of Darwinian theory that seemed to un-

derlie a significant—possibly a major—portion of the archaeology actually being done in the anglophone tradition. To do this, we asked a diverse set of practitioners to explicitly address the role of Darwinian evolutionary theory in their research. The strongly positive response on the part of the participants and the audience supported our assessment of the growing importance of evolutionary theory in late-20th century archaeology. In the wake of the symposium, we felt that a compilation of papers highlighting the applicability of neo-Darwinian evolutionary theory in an even wider range of archaeological research programs would be of interest and value to the discipline. This volume is the result. It does not seek to be a manual for the employment of evolutionary theory in archaeology. What we have attempted to do is to portray a wide cross-section of the discipline to illustrate the pervasiveness, versatility, and utility of evolutionary theory in archaeological explanation. We do this with the hope of stimulating anew explicit discussion of general theory of social change and promoting the applicability of neo-Darwinian processes in the scientific study of human behavior and society.

THE APPLICATION OF EVOLUTIONARY THEORY TO CULTURAL SYSTEMS

To introduce this volume, some general remarks about the applicability of neo-Darwinian evolutionary theory (shortened to simply evolutionary theory in the following discussion) to cultural systems are in order. What is evolutionary theory? In the broadest sense, it is a theory to explain change. Evolution simply refers to change over time. No one questions that human behavioral systems (that is, 'cultures') change. But how do we explain this change, as opposed to simply recording its occurrence?

Evolutionary theory postulates that culture change results from the differential persistence, through time, of behavioral variation, and that this persistence can be explained through the application of a limited number of universal processes. How these processes operate and interact with each other in any particular case is complex and, at one level, always unique because their result is conditioned by environmental and historical circumstances. Nevertheless, their universality means that generalizations can be made for similar sets of circumstances, allowing us to explain patterns of variation in cultural systems. While few would question the application of evolutionary theory to biological systems, including humans as a biological species, why should it also apply to human behavioral systems? We can propose at least two logical reasons. The first has to do with the relationship between biology and behavior.

As anthropologists, we accept the importance of the relationship between biology and behavior for humans, but we often fail to fully appreciate its implications. It is well understood that the phenotype results from the interaction of the genotype and the environment, and that evolutionary processes (except for mutation) do not work directly on the genotype, but rather on the phenotype. However, these forces only affect the phenotype via the interaction between the phenotype and the environment. This phenotype/environment interface is behavior in its broadest sense. Seen in this light, behavior is the place where evolutionary forces have an effect. These forces affect the phenotype according to the behavior it exhibits. Furthermore, they mediate the differential transmission of behavior to others—regardless of how it is accomplished.

Another way to look at the applicability of evolutionary theory is from a systems perspective. There are fundamental similarities between biological and behavioral systems that cause evolutionary processes to affect these systems in similar ways. Both can be characterized as information-transmitting, self-replicating, negentropic, open systems. Information about both biological and cultural systems is transmitted from component to component within each system. This includes information about the operation and structure (i.e., relationships among components) of the system. Information transmission is not perfect, however, introducing variation. In this regard, imperfect transmission is as vital for evolution as information transmission itself.

Both biological and cultural systems maintain temporal continuity through the replication of their components and structure. Information about the system is transmitted from component to component during self-replication, making the current state of a system strongly conditioned by its previous state.

The negentropic and open characters of biological and cultural systems are closely related. These systems transform energy into more complex, structured forms in a variety of ways. That is, they operate to counter entropy. Results of this are the highly structured nature of these systems and their dynamic temporal continuity through self-replication.

Another outcome is that both biological and cultural systems tend toward expansion. To accomplish this, these systems must continuously take in energy. In the real world, however, the availability of energy is limited, and varies in both time and space. This encourages competition for available energy needed to maintain these systems, and the differential persistence of variants over time according to their abilities to successfully capture energy sufficient for continued information transfer and replication. The end result of the interaction of these

various characteristics is vectored (that is, historical) change in these systems.

Regardless of how compelling such logical reasoning may or may not be, the archaeological community will not be convinced of the applicability of evolutionary theory to cultural systems on the strength of logical arguments alone. Nor will it respond to continual criticism of its inability to understand or utilize evolutionary theory. In the end, evolutionary theory must be better theory to be accepted broadly across the field. It must satisfy a performance standard. That is, it must better explain the archaeological record by accounting for more phenomena and by doing so more parsimoniously.

MISCONCEPTIONS ABOUT EVOLUTIONARY THEORY

As noted above, a review of current archaeological literature shows that many, perhaps most, anglophone archaeologists regularly utilize some version or components of evolutionary theory in explanations of culture change. Examples include concepts of adaptation and diffusion, and seriations that depend on the stochastic effects of drift. There are a number of misconceptions about evolutionary theory and its role in archaeological explanation, however, that prevent its wider application.

Back to Nature

The first of these perceives evolutionary theory as dealing solely with the interaction between humans and the natural environment. The primary problem here is a misconstrual of the concept of environment in evolutionary theory; it is not limited to the natural world, but refers to the complete—and often complex—context in which behaviors take place. The social environment is important in biology (in sexual selection, for example); it is at least as important as the 'natural' environment for humans, if not more so. A related 'back to nature' misconception is that evolutionary theory only applies to economic behavior. In truth, evolutionary processes are as applicable to ideational aspects of culture as they are to the more material ones. Recent examples include Neiman's work with style and social interaction (1995), Barton, Clark, and Cohen's (1994; Clark, Barton & Cohen 1996) model for European paleolithic art, Graves and Ladefoged's (1995) study of Polynesian ceremonial architecture, and a number of the contributions to this volume. Worse is the misconception that evolutionary theory is uncivilized. That is, it only applies to hunter/gatherers. As many of this volume's contributors show,

general theory to explain culture change is as useful and necessary for complex as for simple societies.

Spencerisms and Social Darwinism

If 'back to nature' misconceptions relate to the application of evolutionary theory to archaeological questions, 'Spencerisms' involve fundamental misunderstandings of evolutionary theory in general—especially the concepts of selection and vectored change. Evolutionary theory is not a revived 'social Darwinism'. The specialization implied by social Darwinist 'survival of the fittest' scenarios may have appeared successful in the short-term. However, a better understanding of evolution shows that the maintenance of diversity provides a greater potential to deal with inevitable environmental change, and seems a better strategy for long-term success. This seems to be characteristic of humans as a species.

Thomas Malthus long ago pointed out the relationships between mortality-producing agents such as disease, starvation, and war on human population. Accepting these relationships does not mean, as 19th-century social Darwinists proposed, that we should condone them as inevitable. On the other hand, saying that we do not condone such agents does not make them untrue.

Related to the above is the misconception that evolution equals selection. Certainly selection is important. But non-Darwinian processes, such as drift, are clearly as important in cultural systems as they are in biological systems. Moreover, they probably played an especially important role in the small, semi-isolated social groups that comprised such a large part of the human past.

Finally, evolutionary theory is not progressivist. As repeatedly pointed out (e.g., Rindos 1989) evolution is non-directional in the sense that there is no progression toward any cultural stages or levels of social complexity. To the uncritical appraisal, evolutionary change may *appear* to be so because it is vectored through time (though in no predetermined direction) and changes are cumulative, building on the past. This, of course, does not preclude patterning in human systems or similarities in adaptive postures among societies in similar contexts, nor does it require such similarities.

Exceptions to the Rule

'Exceptions to the rule' are often in the form of cautionary tales. These are indeed useful in avoiding overly facile application of general theory. Gould and Lewontin's (1978) classic argument against overly-simplistic application of the concept of adaptation (see Chapters 5 and 12), and O'Brien and Holland's (1992) revisiting of this issue in archaeology are good examples. Such

'exceptions' also have been portrayed, however, as invalidating general theory. While caution is useful, these again often result from misconceptions about explanatory theory in general and evolutionary theory in particular. We mention two examples here.

The first is the existence of unique culture histories that supposedly invalidates the applicability of general explanatory theory (see papers in Nitecki & Nitecki 1992, Clark 1993). All culture histories—like the histories of each biological species—are indeed unique. In fact, from a neo-Darwinian perspective, undirected change and the complex interaction of environmental and historical circumstances virtually assures uniqueness in cultural trajectories (Rindos 1989). However, the uniqueness of histories does not preclude the generality of the processes that govern them. One should not confuse the two.

The second exception we mention is the existence of apparently maladaptive behaviors. First, we must be aware of the possibility of ethnocentrism, and recognize the importance of context in evaluating fitness. One society's maladaptation could be another's success. Furthermore, many behaviors are, for all practical purposes, selectively neutral. The significance of non-Darwinian processes such as drift has been mentioned above. The occurrence of selective neutrality in behavior, and its effect on the archaeological record is clearly important. Without it, the seriations upon which so many archaeologists depend would not work very well (Chapter 8, Teltser 1995b). Furthermore, individual behaviors do not occur in isolation, but comprise a tightly and complexly integrated set that we call culture. Apparently maladaptive behaviors may be 'packaged' along with those that are strongly favored by selection. This concept, also called 'sorting' (Ramenofsky 1995, see also Chapter 4) is also recognized for biological structures.

With respect to apparently maladaptive behaviors, we should also keep in mind what we call the 'good enough' principal, recently discussed for human behavior by O'Brien and Holland (1992). That is, a behavior does not have to be optimal to be selected for; it only has to be good enough—that is, it only has to be a little better than competing behaviors.

Person to Person

The last group of misconceptions we want to discuss concerns the idea that evolution is dehumanizing. That is, evolutionary theory focuses on mechanistic forces (often seen as 'external' to human society) and ignores the very aspects that make us human—emotions, desires, and especially intent. This is due in a large part to misunderstanding the nature of evolutionary processes and

the role of the environment. Evolutionary processes are not some sort of external 'forces' that direct human destiny, but an integral part of the operation of human systems. Evolutionary change is not imposed from without, but the result of human choice. Over time, individuals perform 'behavior A' less and less frequently, and perform alternative 'behavior B' more and more frequently. This is the essence of change seen from an evolutionary perspective. Why B becomes more frequent at the expense of A is the fundamental subject of inquiry from this same perspective. All human behavior and behavioral change takes place in a context. This is the environment. In one context, A may replace B; in another B may replace A. Does the environment determine behavior? No, but the outcome of any behavior, and its effect on whether or not people continue to perform it is often affected in some way by the context in which it takes place.

In evolutionary theory, the role of the individual is not precluded *a priori*. In fact, when change is viewed as the differential persistence of behavioral variation, the individual assumes a much more important role in evolutionary theory than in many other explanations that see change in terms of transformation at the level of 'culture'. As in biological systems, evolutionary processes operate at the level of the individual, even though their effects are manifest at the population level. Granted, the individual is difficult to resolve in prehistory. But this is a problem with the record and our abilities to interpret it, not an indictment of evolutionary theory. As seen in Chapters 4 and 9, evolutionary theory may help to better resolve individuals in prehistory.

Emotions, desires, intent, and other aspects of human consciousness also are not excluded *a priori* from interest in an evolutionary perspective. However, they too are often difficult or impossible to access in the archaeological record. As a scientific discipline, archaeology seeks general, testable explanations for human phenomena. While human feelings often may not serve to adequately account for the archaeological record, this does not negate their existence nor potential importance. Especially contentious is disagreement over the role of intent, although it is not always clear what is meant by intent. People intend to do many things, but this explains little. As O'Brien and Holland point out, "Many early aviators must have leapt from cliffs, propelled by hopeful inventions and the intent of flying. Ultimately, it was the ability to overcome gravity—not intent—that determined which aviators survived to pass their genes and inspiration on to others." (1995a: 180). An evolutionary approach focuses on why some are more successful and some are less so—regardless of their intent.

Along the same lines, evolutionary approaches are somehow felt to ignore human inventiveness and prob-

lem solving abilities. This misconstrual is more understandable given discussions in some of the theoretical literature (e.g., O'Brien & Holland 1990, 1995a, Rindos 1989). Nevertheless, the important point made in these and other somewhat less rigid applications of evolutionary theory is the conceptual separation between the origin of variation and its differential persistence through time. Only the latter process effects long-term change. Human problem solving introduces new behavioral variation into a cultural system. This variation is then subject to selection, drift, sorting/packaging, or other evolutionary processes. A new solution may indeed spread because it is somehow 'better' than existing alternatives—i.e., selection—but this is not guaranteed. It may also spread for other reasons (possibly due to selection, but also due to drift, packaging, or other processes), even at the expense of alternative 'better' solutions. Again, humans are constantly attempting to solve problems and human inventiveness regularly introduces new behavioral variants. However, the invention of a new solution does not mean that it will spread (as the majority of inventors filing patents learn). Separating the differential persistence of variants from the creation of variation is one of the conceptual milestones of Darwinian theory and a fundamental reason for its success in explaining change (see Chapter 5 for additional discussion of this point).

Because change is a result of the differential persistence of variation, most evolutionary theorists have focused primarily on the processes responsible for sifting variation and have paid less attention to those responsible for creating it. However, as discussed below, we should probably pay more attention to the origin of variation in human systems.

SCALES OF APPLICABILITY

An important aspect of evolutionary theory is that it operates and can be invoked in explanation at a wide variety of different temporal, socioeconomic, and operational scales. Hence, we should expect that research programs based in an evolutionary framework should similarly approach the archaeological record at different scales. The papers in this volume exemplify such diversity, ranging from studies of the earliest hominids to modern societies, from small-sized egalitarian groups to complex civilizations, and from macroevolutionary approaches to evolutionary ecology to human cognition.

Time Depth

The entire suite of papers show the applicability of evolutionary theory at various time depths and, hence,

at varying degrees of archaeological resolution. At one extreme are the chapters by Geoff Clark (Chapter 12) and John Gowlett (Chapter 3) dealing with Pliocene and Pleistocene hominids. Gowlett reviews a wide variety of evolutionary models for dealing with human biocultural evolution through the Pliocene and Pleistocene, differentiating those that employ direct archaeological evidence and those that use comparative, uniformitarian analogy with modern humans and other primates. These approaches are exemplified in Clark's paper. He uses evolutionary theory to structure and support the use of modern human and primate behavior in order to reconstruct aspects of Pliocene hominid sociality that may not be visible in the archaeological record.

At the other temporal extreme are the chapters by Polly Weissner and Douglas Bird (9 and 16, respectively). Weissner uses her ongoing study of style among the modern !Kung San to explore the evolutionary bases for aspects of cognition. She focuses on social identification via comparison, cultural transmission, and communication through style. Bird establishes foraging theory within a Darwinian framework, using shellfish collecting by the Meriam of Melanesia as a case study. He then examines the relationships between foraging behavior and archaeological residues.

Socioeconomic Complexity

Evolutionary theory also scales across the range of social complexity and economic systems found in human cultural systems. The chapters just mentioned focus on a variety of relatively small-scale forager societies, as do several others. Others address issues at more complex scales of socioeconomic organization.

Michael Shott (Chapter 11) examines the effects of community size and complexity on cultural transmission processes and lithic morphology in the context of a Mississippian settlement in the central United States. Michael Diehl (Chapter 14) uses a behavioral ecological approach and optimality modeling to evaluate models for incipient agriculture among semi-sedentary late Archaic populations of the Tucson Basin, in the southwestern United States. Hector Neff and Daniel Larson (Chapter 5) compare the spatial and temporal distributions for ceramic design and composition to assess the development of region-level craft and subsistence specialization in coastal Guatemala and the Colorado Plateau of southwestern North America. And Fraser Neiman (Chapter 15) develops an evolutionary basis for the linkage between political power and wasteful consumption. He applies this to Maya stela construction and terminal monument dates, and uses statistical modeling to clarify the timing and causes of the Maya collapse.

Methodological Diversity

In archaeology, as in biology, there are significant theoretical and methodological differences between those whose interest lies in the operation of formal Darwinian processes in a historical context and those who focus more on the dynamics of relationships among individuals, societies, and the environment writ large. In general the former macroevolutionary approaches share several general objectives. They attempt to identify the effects of macroevolutionary processes like selection or drift on the spatial and temporal distribution of behaviors and their material residues. They also often focus on ways to recognize and distinguish the process(es) responsible for these effects. Such work helps to clarify the meaning of different dimensions of variability in the archaeological record, and to provide general explanations for broad patterns. It also helps to define and formulate questions about human behavior and map out ways to address them. Lee Lyman and Michael O'Brien (Chapter 2) take this approach to outline the history of evolutionary thought in American archaeology over the past century. A formal Darwinian perspective also characterizes the above mentioned chapters by Neff and Larson and by Neiman.

Still, as the above authors would agree, to simply state that a phenomenon is the result of selection, for example, isn't a very complete or useful explanation in that we don't learn very much about human behavior (see, e.g., Jones, Abbott & Leonard 1995; O'Brien & Holland 1995). Selection, or other macroevolutionary processes, is not a giant hand from on high sorting behaviors to preserve and to discard. We need to understand how and why macroevolutionary processes operate, both in general and in particular cases. How do behaviors get selected? Under what conditions does drift operate? This is an important role of evolutionary ecology and related studies. Douglas Bamforth and Peter Bleed (Chapter 7) discuss the potential value of this ecological perspective on evolutionary change. They propose a more explicit definition for the concept of risk, within a more general evolutionary framework, noting that risk involves assessments of both the possibility and cost of failure. They use several test cases to examine human technological behavior in the context of variation in the nature of risk along these dimensions.

Esmée Webb and David Rindos (Chapter 13) also employ the perspective of evolutionary ecology to assess the ways in which landscapes are initially colonized by humans. They model differences in realized carrying capacity resulting from the degree to which colonizers are preadapted to the environments of uninhabited territory (due to its similarity or difference from their homeland) and its effects on the mode and tempo of colonization.

They test this model for Pleistocene Sahul and North America. The chapters by Bird and Diehl, mentioned above, are also strongly ecological in perspective.

On the other hand, these studies still need to operate within a general evolutionary framework for the development and evaluation of ecological models, and to make them relevant to the long-term patterns of change and stability seen in the archaeological record. It is clear that while all foraging may be optimal in some sense, some foraging is more optimal than others (with apologies to George Orwell). That is, optimality is not a universal law, like those of thermodynamics; it is a behavioral tendency that is widely observed in the archaeological (and biological) record. Both the widespread appearance of this tendency, and those circumstances under which it does not appear to hold, still call for explanation. To do this, we must seek recourse in more formal and mechanistic evolutionary processes, points cogently made in the chapters by Neiman and Mithen.

Mithen (Chapter 4) makes the case for long-term selective pressure affecting the evolution of human cognition, and underlying many of the behavioral regularities observed by evolutionary ecologists. He also points out that some important domains of human behavioral systems (e.g., religion) may be evolutionary 'spandrels' (cf. Gould & Lewontin 1978). That is, they are simply neutral consequences of selection acting on other characteristics and hence might not be explainable by formal Darwinian selection or by ecological models of optimality. This is discussed further below in the context of 'sorting'.

Biologists have been arguing the relative merits of these positions for decades (see summaries in Chapters 5 and 7) and, in recent years, archaeologists have entered the fray. However, the merits of each approach are often closely tied to the types of questions asked (proximate versus ultimate causality), the time frame of interest (synchronic versus diachronic), and the geography of applicability (local versus regional). Both approaches are very useful and should better be considered as conceptual tools to apply evolutionary theory at different scales appropriate to the focus of research in particular problem domains.

In addition to approaches that directly parallel those of evolutionary biology, several others are represented in the papers collected here. Drawing from evolutionary psychology, ethology, and to some extent from sociobiology, the previously mentioned chapters by Steven Mithen and Polly Wiessner (4 and 9) explore the evolutionary basis of human cognition and its effects on behavior manifest in the archaeological record. Both studies employ aspects of macroevolutionary and ecological models for developing explanations of human behavioral systems.

In something of an intermediate position are chapters that deal with the relationships between human behavioral systems and the material residues that comprise the archaeological record—an area that has often been considered under the rubric of 'middle range theory'. While most of the papers deal with this interface to varying extents, several do so in more detail. Robert Bettinger and Jelmer Eerkens (Chapter 10) and Michael Shott (Chapter 11) closely examine the effects of different processes of cultural transmission on the morphology and variability of Great Basin projectile points. Michael Barton (Chapter 8) employs Darwinian and non-Darwinian processes to construct inference chains between stone tool morphology, technological behavior, and social organization—especially social group membership. At a more general level, Peter Bleed (Chapter 6) develops theory, with evolutionary underpinnings, for human technology. Of importance to archaeologists, his goal too is to forge explicit and theoretically sound links between technological 'content' (including standards, information, and behavior) and 'results' (including material culture, environmental modification, and social organization).

While the essays collected here intentionally represent an extremely wide array of interests, covering much of the territory represented by the discipline as a whole, all the contributors share a common interest in applying neo-Darwinian evolutionary theory to human behavioral systems. Nevertheless, they differ (sometimes strongly) as to how this should best be accomplished. We think that this diversity is a strength of the volume, and a positive and encouraging sign. Only through overt discussion of theory—including marked disagreement at times—accompanied by the explicit application of theory to archaeological problems and rigorous testing of theory against pattern manifest in archaeological records can we begin to build a better, more scientific archaeology.

ISSUES TO BE ADDRESSED

Rediscovering Darwin attempts to portray the current state of the discipline with regards to the application of Darwinian evolutionary theory to archaeological problems. In so doing, it brings together a diversity of approaches and solutions. Most evolutionary theorists in archaeology have called for an expansion of current Darwinian theory to encompass behavioral systems as well as biological systems. As shown in this volume, this has been initiated in a number of dimensions. We feel that the discipline has matured considerably in the development of general theory of behavioral change and its use in archaeological explanation. It is also clear from this book and from other current literature, however, that

several important areas need to be more intensively investigated. We briefly address several of these issues with the hope of stimulating further thought and discussion.

Explanation and Evolutionary Units

There is a need for serious discussion about what is being explained in archaeology. Is it the archaeological record *per se* or the behavior that produced it? Recent discussions by Robert Dunnell (1995) and Michael Schiffer (1996) are pertinent in this regard, as is the Neff and Larson chapter. It seems that archaeology is more satisfying to most practitioners and more valuable to non-archaeologists if it includes the latter, as well as the former. However, claiming that we are explaining behavior alone is overly simplistic. Material culture undeniably comprises an important component of the human phenotype. It predates the appearance of the genus *Homo* and is as fundamental to being human (and surviving as humans) as our bipedalism. Material culture also clearly varies across space and time, and explaining this phenotypic variation is essential to understanding the human past. Furthermore, regardless of our interest in past behaviors, the material record is all that remains. Fundamentally, *all* archaeological explanation must explain the archaeological record.

Nevertheless, we cannot lose sight of the fact that the archaeological record is but an irregularly preserved residue of a much richer set of human behaviors. The items that remain for archaeological study participated in complex, integrated human behavioral systems that are no longer directly visible. Failure to appreciate this complexity can lead to overly atomistic explanations and naïve adaptationist 'just so' stories (see Clark, Chapter 12).

Evolutionary processes often did not operate directly on the material culture that forms the present archaeological record, but on the behaviors that originally produced it and led to its incorporation in the record. In many respects, the archaeological record is the result of evolutionary processes acting on human behavior. In Chapter 5, Neff and Larson cogently argue that the inference chains linking the material record with past human behaviors are most reliable if they are short and explicit. While explicit inferences are always desirable, however, short chains are not always possible. The fact that material residues are all that remains of past human behaviors does not mean that our explanations cannot go beyond these residues, as is shown in Clark's chapter. The same is true for most other branches of science—especially the life sciences where explanations for evolutionary change must often come to grips with very incomplete remains of organisms that were unlike any

modern creatures and have no living descendants (e.g., Erwin, Valentine & Jablonski 1997).

Origin of Behavioral Variability

As noted, a fundamentally important aspect of neo-Darwinian theory is the distinction between the origin of variation and the differential persistence of variation. The latter process, because it directly causes behavioral change, has generally been the focus of most theoretical discussions in archaeology. Closely paralleling evolutionary thought in biology, the origin of behavioral variation has generally been treated as potentially interesting from a humanist viewpoint, but inconsequential with regard to accounting for change. The general disregard of the origin of variation is understandable from the biologist's point of view. Because organisms have no control over the nature or frequency of mutations, their occurrence often can reasonably be treated as essentially a random process, although even at a molecular level this is not entirely accurate.

Nevertheless, the processes responsible for change, like selection and drift, are themselves controlled in part by the amount of variability available, the nature of that variability (e.g., its relative neutrality or fitness coefficient), and the rate at which new variability arises. Furthermore, it is not clear that the origin of *behavioral* variability can be treated as an effectively random process with the same impunity as can genetic mutation.

Dunnell (1978) has argued that the rate at which behavioral variants arise might be linked to absolute population size, and that the rate of new variants per individual may be relatively stable. This may be an overly simplistic view, however. For example, population density—in addition to absolute numbers—may also play a compounding role. More people in a social group means more opportunity for the exchange of ideas and their recombination in novel ways. It also means that each individual has a better chance to learn about—and avoid—'unsuccessful' behaviors. Increased population density might act to amplify variability, as sexual reproduction does for biological systems, increasing the rate at which variation arises and spreads and, consequently, the rate of evolutionary change. This *appears* to be the case with the rise of complex society, for example, and some form of empirical testing seems warranted.

Other factors may also affect the rate at which new variation appears. Situations of extreme stress, for example, may increase the rate of behavioral variant creation. An admittedly vague but useful concept, stress can be generalized to refer to the severely reduced effectiveness or failure of a set of previously adaptive behaviors. This is generally due to a change in contextual param-

eters (i.e., the physical or social environment) such that behavioral outcomes exceed acceptable tolerance limits. More obvious examples include social systems that become unable to adequately resolve interpersonal problems and maintain social cohesion, or technological systems that can no longer provide sufficient subsistence resources. Such stress may increase the rate at which novel behaviors are generated. An increase in the amount of variation, in turn, increases the chance that a successful alternative will be produced upon which selection might act. Such a response to stress may itself be the product of long-term selection—a successful adaptation to environmental change that has allowed humans to populate diverse environments across the globe.

In addition to changes in the rate with which variety is generated, it may not be appropriate to treat the actual variants produced as random in all cases. One effect of language is that human knowledge is potentially cumulative. Of course, all evolutionary change is cumulative in some sense, but this effect may play out differently in human behavioral systems than it does in biological systems. A single individual has access, through oral or written tradition, to the experience of many others—including those to whom he or she is unrelated in a genetic sense. This means that many unsuccessful behaviors can be avoided and successful ones can be elaborated when new behaviors are created. This is not to say that all behaviors that appear successful or unsuccessful are ultimately so. ‘Success’ is conditional—dependent upon temporal and spatial scale. However, language may well increase the percentage of potentially successful new variants for selection to work on and reduce potentially deleterious effects of variation reduction due to drift. In this way, the type and amount of information accessible to individuals may non-randomly affect the rate and direction of evolutionary change.

Individuals may also use such cumulative knowledge to make reasonably accurate estimates of the probability of successful transmission prior to introducing a new variant, or they may manipulate those probabilities in favor of the variant they are introducing. In effect, this can give a new behavioral variant a better chance of being favored by selection than would have otherwise been the case (see Dennett 1995: 370-383). In this sense, the origin of new variation might not be completely undirected, as Rindos (1989) has argued.

In an historical example of technological change, Thomas Edison correctly surmised that an incandescent light bulb might successfully replace extant gas and arc lighting. He announced to the press that his research lab was going to develop one. His team not only developed a functional bulb, but also an electrical system infrastructure (i.e., wiring, switching, and generating equipment)

that would make it practical and commercially viable. Together with the advanced publicity and the prestige of his laboratory, these combined to encourage the rapid adoption of incandescent lighting in general, and Edison’s version of it in particular. As much an entrepreneur as a creative genius, he ‘stacked the deck’ to give his new behavioral variant the best competitive position possible. Similar examples have been proposed for the rise of chiefdoms, in specific, and social complexity, in general. Intent doesn’t always equate with success, however, as Edison later learned when he tried to push direct over alternating current. However, such deck stacking may have two somewhat different effects. In some cases it can result in selection favoring a variant that is less beneficial over the long term than others. Given the temporally vectored (albeit non-progressive) nature of evolutionary change, this kind of selection can profoundly affect the direction of change. Over the long-term, it may also increase the probability of the introduction and rapid adoption of potentially successful (or more successful) variants, giving individuals and groups who engage in such behaviors a competitive edge over those who don’t.

This is not to claim that behavioral change is wholly Lamarckian, as some have done. That is, the *origin* of behavioral variation and the processes that control its *transmission* and *persistence* are indeed distinct, and change is still the result of differential persistence of variation, not directed variation. However, those processes responsible for the origin of behavioral variation should be treated within an evolutionary framework. They can have significant effects on the operation of selection and drift and can, in turn, be affected by such evolutionary processes.

The Transmission of Behavior

A little-explored issue central to applications of evolutionary process to human behavioral systems, is the transmission of behavior. It is clearly not genetic (or at least not *directly* genetic) for the majority of human behaviors (but see Chapters 4, 9 and 12), and this has numerous implications, some of which are discussed below. The fact that genetic information is almost exclusively transmitted via mitosis and meiosis (closely related in their operation) may be the primary reason for the restricted number of evolutionary processes identified for biological systems. Non-genetic transmission of behavior is much more varied and flexible, and may involve more processes and more variability in the operation of those processes than now recognized. Cavalli-Sforza and Feldman (1981), and Boyd and Richerson (1985) have opened the systematic treatment of this subject, but considerable work remains to clarify both the mechanisms

of behavioral transmission in human societies and their implications for the application of evolutionary processes. Most evolutionary theorists refer to these studies, often questioning the need for the distinct sets of biological and cultural evolutionary processes, proposed in both works, for dealing with human behavior (e.g., Dunnell 1989, Leonard & Jones 1987, O'Brien & Holland 1990, 1992). However, these workers have done little to either apply them or to suggest alternatives. Notable exceptions include work by Neiman (1995) and the chapters by Bettinger and Eerkens and by Shott in this volume which test Boyd and Richerson's models for cultural transmission against different data sets.

Evaluating Behavioral Fitness

The concept of fitness, as applied to human behavioral systems, remains difficult to define or apply. Fitness—a measure of potential fertility and realized survivorship—is a cornerstone of evolutionary theory. In the operation of evolutionary processes, it is essential to be able to evaluate the relative benefits of alternative expressions of a trait. In biology, this is accomplished by application of the reproductive standard. Defined in terms of differential reproductive success, fitness is a universal, independent (in theory, at least), and empirical measure of the differential survival (both potential and realized) of variability that results from the operation of fundamental evolutionary processes such as selection and drift. Even biologists who employ concepts like group fitness, inclusive fitness, indirect benefits, and kin selection in sophisticated treatments of animal social behavior rely ultimately on the reproductive standard for measuring fitness (e.g., Emlen et al. 1995, Ruse 1987). The same reproductive yardstick is applied, regardless of the trait in question or the evolutionary process involved. The fact that it is not possible to actually observe reproductive success in many real-world situations (e.g., in the fossil record) does not diminish its utility or value to evolutionary theory.

Applying the reproductive standard for fitness to human behavioral systems is problematic for several reasons, however. Primary among these is that there is no demonstrable, direct, genetic basis for most human behavior. This does not mean that behavior does not affect nor is affected by reproductive success, simply that such behavior does not seem to be generated directly by genetic mechanisms (see Chapter 4). Human language is a well-known case-in-point. It has been known for over a century that there are physical structures in the brain (e.g., Broca's area, Wernicke's area) that are directly related to the human capacity for the development of language and its expression in speech. The information nec-

essary for the development of these physical structures is coded in human DNA, and transmitted from one generation to the next via sexual reproduction. However, it is equally well-known that, if an individual is not exposed to language in a context of social learning prior to early adolescence (ca. 12 or 13 years of age), it is unlikely that he or she will ever be able to develop functional language. Hence, the information that codes for the phenotypically expressed behavior that we call language is passed on *both* in the human genome and via social learning.

Arguably, many human behaviors do not have even the partial genetic basis known to exist for language. This suggests that the reproductive standard, as it is now conceptualized, may be an inappropriate fitness measure for human behavior. On the other hand, behavior undeniably *can* affect reproductive success. Also, in the small groups typical of much of the human past, most social learning took place in the context of the biological family. Hence, reproductive success *can* affect the transmission of behavioral information via social learning. Nevertheless, the linkage is indirect and can be 'horizontal', rather than only via the transmission of genetic material 'vertically', from one generation to the next. In fact, it is easy to propose factors other than reproductive success that would affect the transmission of behavioral information even in small social groups comprised primarily of extended families. For example, individuals who live long lives will have a greater opportunity to pass on behaviors to others via social learning, even if they have few or no offspring, than individuals who have many offspring but die young.

This has left evolutionary archaeologists in a bit of a conundrum with respect to explaining the mechanisms of selection or identifying selective neutrality. One answer has been to tie behavior eventually to reproduction, in a manner not unlike sociobiological approaches to human behavioral systems. For example, if two alternative behaviors are postulated to be differentially 'efficient', the more efficient behavior is thought to increase the time available for other behaviors, including those directly related to reproductive success (e.g., Rindos 1984, 1989; Neiman 1995). Similar arguments have been made by sociobiologists (see Dunnell 1989, Ruse 1987). Others have utilized a more paleontological approach to fitness. Leonard and Jones (1987) propose an alternative behavioral fitness measure they term 'replicative success'. Cavalli-Sforza and Feldman (1981: 15) refer to this same concept as 'cultural fitness' (see also Stoltis, Boyd & Richerson 1995, and commentary). Simply put, the fitness of a given behavior can be measured in terms of how it is replicated over time relative to alternatives, in a way somewhat analogous to realized fitness in biology. Leonard and Jones go on to point out that, while all

behaviors will show variable replicative success, some will also affect Darwinian fitness (i.e., reproductive success). They imply that these latter will be subject to selection, while those that do not affect reproductive success might better be explained by stochastic processes such as drift (O'Brien and Holland [1992] explore additional implications of replicative success). Although both approaches make the case that behavior can affect reproductive success, neither deal with the way in which reproductive success can affect the transmission of behavior.

A reasonable solution to this dilemma is to return to the idea that, as archaeologists, we need to expand current evolutionary theory to account for behavioral systems rather than simply import the package from biology (e.g., Dunnell 1989, Jones, Leonard & Abbott 1995). One way to do this for fitness is to build on suggestions made by Neff (1992, 1993, Chapter 5), Dunnell (1989), and Dawkins (1989) and treat the transmission of *information* responsible for behavior as the critical variable, rather than the mechanism by which it is transmitted. This approach requires expanding the concept of genotype to include *all* information needed to produce a phenotype, regardless of transmission mechanism, much like the expanded phenotype concept proposed by some archaeological theorists which includes human behaviors and material culture as well as biological structures (e.g., Dunnell 1989, O'Brien & Holland 1992, 1995b; Jones, Leonard & Abbott 1995; Neff 1993, see also Dawkins 1990).

In other words, fitness should be defined and measured in terms of successful information transmission—both potential and realized—rather than reproduction (or even 'replication' *sensu* Leonard and Jones [1987]). This applies to both biology and behavior. It is often forgotten (or the implications overlooked) that biological *traits* are not passed from one generation to the next; in reality, it is the *information* needed to reproduce these traits (in the form of DNA codons) that is transmitted. In evaluating fitness, reproductive success is simply a more easily measured surrogate for the transmission of genetic information. In the same way, *behaviors* are not transmitted from individual to individual in a social context, but rather the *information* that an individual needs to produce those behaviors that is transmitted in social learning (see also Dennett 1995: 335-369).

An example of this approach considers the set of biological and behavioral mechanisms required to make stone tools. The information needed for the phenotypic expression of grasping hands, precision and power grips is coded in human DNA, and genetically transmitted along descent lines. The information needed to make and use stone tools is stored and coded cognitively, and transmitted from individual to individual via social learning. Both sets of phenotypic characteristics are heritable—that

is, they can be passed from individual to individual with relatively 'high fidelity'. The frequencies of the expression of both sets of phenotypic characteristics over time are conditioned by the probabilities that the requisite information will be transmitted from individual to individual. If the grasping abilities of the human hand positively or negatively affects reproductive success (the way in which genetic information is transmitted), then its frequency will change over time accordingly. The same is true of a set of technological behaviors. If they affect the social learning process positively or negatively, their frequencies will be affected accordingly. Clearly, whether technological behavior has a positive or negative impact on the biological survival of the social unit in which learning takes place will affect the replication of that behavior. However, the reason is not due to a *genetic* basis for lithic technology, and changes in the social transmission of such behavior are not are not simply a result of differential reproductive success.

The point is that we would do better to measure *potential fitness* according to the probability that information needed to code for human phenotypes is transmitted from individual to individual—including the extended phenotypes of learned behavior and associated material culture, as well as biological characteristics—and *realized fitness* according to the extent that such information is transmitted. The way in which such information is stored—DNA, cognitive structure, the written word, or optical disk—and means by which such information is transmitted—through sexual reproduction, oral tradition, libraries, or a computer screen—is irrelevant at a conceptual level (although it *is* relevant in terms of the rate, direction, and other mechanics of transmission [see also Dunnell 1989]).

Decoupling fitness from biological reproduction and redefining it in terms of information transmission more accurately represents the evolutionary process, and has the potential of stimulating better (i.e., more inclusive, more parsimonious) explanations of human behavior and its change. It is especially useful for the many behaviors that have little direct impact—or negative impact—on reproductive success, but which are still replicated. Along these lines, such an expanded fitness concept could be equally valuable in ethology and sociobiology given the importance of learned behavior in vertebrates, and especially in mammals and birds.

Non-Darwinian Processes

Although Dunnell noted the potential importance of non-Darwinian processes such as drift two decades ago (1978), most evolutionary archaeological research—both theoretical and applied—has focused on selection.

Neiman's work (1995) is an exception, and Barton's chapter in this volume focuses on non-Darwinian processes. This perspective has the potential for considerable advancement in our understanding of cultural systems and the vectored changes that characterize them.

Most selectionist literature has a strongly gradualist tone (e.g., Braun 1987, Rindos 1980). Although many are aware of the potential for non-Darwinian processes, they tend to see selection as the overriding force in behavioral change (e.g., Jones, Leonard & Abbott 1995; O'Brien & Holland 1995a). Nevertheless, throughout most of the human past, behavior took place and was transmitted in the context of very small groups. This means that drift and 'behavioral bottlenecks' likely played important roles in behavioral change. For this reason, along with humans' wide geographical distribution and potential for long-distance movement, much of human behavioral change can more accurately be characterized by a punctuated equilibrium model rather than a gradualist one.

Sorting or packaging also probably played an important role in behavioral change, but has yet to be explored. Packaging refers to the fact that traits—including human behaviors—are rarely transmitted as discrete units, but rather as parts of an integrated set (Ramenofsky 1995). For example, use of a particular type of temper in ceramic production can be transmitted as part of a set of pottery making behaviors that included vessel construction, vessel form, surface decoration, and firing conditions. If one of the trait set (e.g., temper) was strongly selected for, the entire behavior set might be favored over another set, even if other specific traits (e.g., those related to vessel form) in the first set had a lower potential fitness than alternative traits in the second. In the 1994 symposium, the presentation by Michael Jochim (1994) addressed the potential for such processes to account for apparent anomalies in an archaeological record. In the present volume, Steven Mithen explores this idea further, focusing on religious practices. He suggests that such processes may be important for understanding the evolution of complex behavioral systems, such as food production.

EXPLANATION IN ARCHAEOLOGY

The human experience is diverse and complex, and can be approached in many ways. Of those that have more time depth than a generation, religion, art, folklore, and history exemplify some of the very different perspectives we can adopt to try to make sense of ourselves and our past. Of the many fields of study deal with the human experience, only archaeology and its sister discipline of physical anthropology employ a scientific

paradigm to access the human past. And only archaeology focuses on the behavioral systems we call 'culture' that make us unique among the living organisms of this planet.

The scientific paradigm does not inherently warrant archaeology with a better claim to 'truth' about the human experience, nor does it imply that the meaning of humanness is somehow less accessible to archaeology. However, given the considerable success of the materialist world view of western science in accounting for many aspects of reality, applying it to ourselves should provide equally valuable insights. While there are archaeologists who feel that a scientific paradigm is an inappropriate one for the discipline, we wish to point out that there is no other discipline that employs a scientific approach to the study of the human past. In the century of so of its existence, archaeologists have learned more about our past and how we came to be the way we are than in all the preceding millennia for which we have written records—and this despite a continuous interest in our origins. To abandon the only scientific conceptual framework for the study of our heritage would be as much a loss to our self-understanding as to abandon historical or artistic inquiry.

Archaeology cannot, nor should it, encompass all avenues to an understanding of the human past. If it is unable to account for aesthetic genius or the depths of the human spirit, this should not be taken as a failure of the discipline. Other scholarly endeavors may be better equipped to cope with these questions. If archaeology fails to do good science, however, this is a more serious matter. Archaeology has claimed a scientific approach since its beginnings as a formal field of inquiry in the last century. Despite well-intentioned self-critique as to the adequacy of science for studying the past, most practitioners and those outside the field consider archaeology to be a scientific endeavor. The success of the discipline, both in terms of its internal goals and from the standpoint of the non-archaeological public, hinges on its ability to do good science.

An overt aim of this volume is to promote better scientific study of the human past on the part of the discipline. As others have argued before us, a powerful, unifying body of general theory is fundamental to the successful application of the scientific paradigm. We think that neo-Darwinian evolutionary theory, expanded to encompass human behavioral systems, is the best candidate for this role. However, as Robert Bettinger and Jelmer Eerkens point out in their chapter there is, "...an unfortunate parallel between evolutionary theory and the weather: everyone talks about it but no one does anything about it". We hope this volume will contribute to efforts to improve this situation.

REFERENCES CITED

- Barton, C. Michael, G.A. Clark & A. Cohen
1994 Art as information: explaining Upper Palaeolithic art in western Europe *World Archaeology* 26: 185-206.
- Boyd, R. & P.J. Richerson
1985 *Culture and the Evolutionary Process*. Chicago: University of Chicago Press.
- Braun, David P.
1987 Coevolution of sedentism, pottery technology, and horticulture in the central Midwest, 200 B.C. - A.D. 600. *Emergent Horticultural Economies of the Eastern Woodlands* (W.R. Keegan, ed.), pp. 153-181. Carbondale: SIU Center for Archaeological Investigations, Occasional Paper No. 7.
- Cavalli-Sforza, L. L. & M. W. Feldman
1981 *Cultural Transmission and Evolution: a Quantitative Approach*. Princeton: Princeton University Press.
- Clark, G.A.
1993 Review: *History and Evolution* (Nitecki & Nitecki, eds.). *The American Journal of Physical Anthropology* 90:129-130.
- Clark, G.A., C. Michael Barton & Alison Cohen
1996 Explaining art in the Franco-Cantabrian refugium: an information exchange model. In *Debating Complexity* (D. A. Meyer, P.C. Dawson and D.T. Hanna, eds.), pp. 241-253. Calgary: Archaeological Association of the University of Calgary.
- Dawkins, Richard
1989 *The Selfish Gene*. Oxford: Oxford University Press.
1990 *The Extended Phenotype: the Long Reach of the Gene*. Oxford: Oxford University Press.
- Dennett, Daniel C.
1995 *Darwin's Dangerous Idea: Evolution and the Meanings of Life*. New York: Simon & Schuster.
- Dunnell, Robert C.
1978 Style and function: a fundamental dichotomy. *American Antiquity* 43: 192-202.
1989 Aspects of the application of evolutionary theory in archaeology. *Archaeological Thought in America* (C.C. Lamborg-Karlovsky, ed.), pp. 35-49. Cambridge: Cambridge University Press.
1995 What is that actually evolves?. *Evolutionary Archaeology* (P.A. Teltser, ed.), pp. 33-50. Tucson: University of Arizona Press.
- Eiseley, Loren C.
1958 *Darwin's Century*. New York: Doubleday & Company.
- Emlen, Stephen T., Peter H. Wrege & Natalie J. Demong
1995 Making decisions in the family: an evolutionary perspective. *American Scientist* 83: 148-157.
- Erwin, Douglas, James Valentine, & David Jablonski
1997 The origin of animal body plans. *American Scientist*. 85: 126-167.
- Gould, Stephen J. & Richard Lewontin
1978 The spandrels of San Marco and the panglossian paradigm: a critique of the adaptationist programme. *Proceedings of the Royal Society* 205: 581-598.
- Graves, Michael & Thegn Ladefoged
1995 The evolutionary significance of ceremonial architecture in Polynesia. In *Evolutionary Archaeology* (P.A. Teltser, ed.), pp. 149-174. Tucson: University of Arizona Press.
- Jochim, Michael
1994 Chance, History, and Context in Evolutionary Change. Paper presented at the annual meetings of the Society for American Archaeology, Anaheim, California.
- Jones, G.T., A.L. Abbott & R.D. Leonard
1995 The structure of selectionist explanations in archaeology. In *Evolutionary Archaeology* (P.A. Teltser, ed.), pp. 13-32. Tucson: University of Arizona Press.
- Leonard, R.D. & G.T. Jones
1987 Elements of an inclusive evolutionary model for archaeology. *Journal of Anthropological Archaeology* 6: 199-219.
- Neff, Hector
1992 Ceramics and evolution. *Archaeological Method and Theory* 4: 141-193.
1993 Theory, sampling, and analytical technique in the archaeological study of prehistoric ceramics. *American Antiquity* 58: 23-44.
- Neiman, Fraser
1995 Stylistic variation in evolutionary perspective: inferences from decorative diversity and interassemblage distance in Illinois Woodland ceramic assemblages. *American Antiquity* 60: 7-36.
- Nitecki, M. & D. Nitecki (eds.)
1992 *History and Evolution*. Albany: State University of NY Press.
- O'Brien, Michael J. (editor)
1996 *Evolutionary Archaeology: Theory and Application*. Salt Lake City: University of Utah Press.
- O'Brien, Michael J. & Thomas D. Holland
1990 Variation, selection, and the archaeological record. *Archaeological Method and Theory* 2: 31-79.
1992 The role of adaptation in archaeological explanation. *American Antiquity* 57: 36-59.
1995a The nature and premise of a selection-based archaeology. *Evolutionary Archaeology* (P.A. Teltser, ed.), pp. 175-200. Tucson: University of Arizona Press.
1995b Behavioral archaeology and the extended phenotype. *Reconstruction Theory: a Behavioral Approach to the Archaeological Record* (A.E. Nielsen, J.M. Skibo, and W.H. Walker, eds.). Salt Lake City: University of Utah Press.
- Ramenofsky, Ann F.
1995 Evolutionary theory and Native American artifact change in the postcontact period. In *Evolutionary Archaeology* (P.A. Teltser, ed.), pp. 129-148. Tucson: University of Arizona Press.
- Rindos, D.
1980 Symbiosis, instability, and the origins and spread of agriculture: a new model. *Current Anthropology* 21: 751-772.
1984 *The Origins of Agriculture: an Evolutionary Perspective*. New York: Academic Press.
1989 Undirected variation and the Darwinian explanation of cultural change. *Archaeological Method and Theory* 1: 1-45.
- Ruse, Michael
1987 Evolutionary models and social theory. *Prospects and Problems: Evolutionary Theory in Social Science* (M. Schmidt & F.M. Wuketits, eds.), pp. 23-48. Dordrecht: D. Reidel.
- Schiffer, Michael B.
1996 Some relationships between behavioral and evolutionary archaeologies. *American Antiquity* 61: 643-662.
- Stoltis, J., R. Boyd, & P.J. Richerson
1995 Can group-functional behaviors evolve by cultural group selection? An empirical test. *Current Anthropology* 36: 473-494.
- Teltser, Patrice A. (editor)
1995a *Evolutionary Archaeology: Methodological Issues*. Tucson: University of Arizona Press.
1995b Culture history, evolutionary theory, and frequency seriation. In *Evolutionary Archaeology* (P.A. Teltser, ed.), pp. 151-68. Tucson: University of Arizona Press.