J Archaeol Res (2007) 15:239–274
DOI 10.1007/s10814-007-9013-z

Cultural Transmission Theory and the Archaeological Record: Providing Context to Understanding Variation and Temporal Changes in Material Culture

Jelmer W. Eerkens · Carl P. Lipo

Published online: 4 August 2007

Abstract Cultural transmission (CT) is implicit in many explanations of culture change. Formal CT models were defined by anthropologists 30 years ago and have been a subject of active research in the social sciences in the ensuing years. Although increasing in popularity in recent years, CT has not seen extensive use in archaeological research, despite the quantitative rigor of many CT models and the ability to create testable hypotheses. Part of the reason for the slow adoption, we argue, has been the continuing focus on change in central tendency and mode in archaeology, instead of change in dispersion or variance. Yet archaeological research provides an excellent data source for exploring processes of CT. We review CT research in the anthropological sciences and outline the benefits and drawbacks of this theoretical framework for the study of material culture. We argue that CT can shed much light on our understandings of why material technology changes over time, including explanations of differential rates of change among different technologies. We further argue that transmission processes are greatly affected by the content, context, and mode of transmission and fundamentally structure variation in material culture. Including ideas from CT can provide greater context for explaining and understanding changes in the variation of artifacts over time. Finally, we outline what we feel should be the goals of CT research in archaeology in the coming years.

Keywords Cultural transmission · Evolutionary archaeology · Artifact variation

J. W. Eerkens (✉)
Department of Anthropology, University of California Davis, One Shields Ave, Davis, California 95616, USA
e-mail: jweerkens@ucdavis.edu

C. P. Lipo
Department of Anthropology, California State University Long Beach, 1250 Bellflower Blvd, Long Beach, California 90840, USA

Introduction

"*Nothing from nothing ever yet was born.*" (Lucretius 50 BC)

The notion that forms are inherited from one individual to another has a long history. As indicated in the opening quote, as early as 50 BC the Roman philosopher Lucretius noted that all things have precedent in something else. Indeed, one of the core notions in our understanding of history in general, and evolutionary studies in particular, is the idea that living things vary in the degree to which they are similar and related due to common descent.

Explaining similarity and change in artifacts over time has been a long-standing goal of archaeologists. The culture historians of the first part of the 20th century were interested in using similarity in assemblages of artifacts, measured along numerous dimensions including form, function, and style, as a means to tell time. The more similar two assemblages or artifact types were, the more historically related and closer in time they were assumed to be. Artifact typologies were created to measure time, much like biologists and paleontologists did with taxa and living organisms (Lyman 2000; Lyman et al. 1997). Culture historians were interested in *how* these sequences varied from place to place and over time. Although culture history continues to form a central component for archaeological inquiry, focus now includes explaining other aspects about artifact variability beyond typology, including explaining *why* artifacts change the way they do. This is where models of cultural transmission can play a role in archaeological theory.

Culture transmission (hereafter, CT) theory follows on Lucretius, Darwin, and the culture historians as a means to *explain* variation, similarity, and relatedness. CT is simply the idea that similarity in behavior and artifacts may be caused by the exchange of information using a nongenetic mechanism. Despite its use in biology, psychology, and other disciplines, CT has not seen widespread application in archaeological research. We do not attempt to summarize or describe research in all these different fields, but instead focus on applications in archaeology and cultural anthropology when relevant. Our goals in this article are to introduce the concepts and goals of CT within the archaeological sciences using simple terms that nonpractitioners can understand. We also aim to examine when CT theory can help make sense of prehistoric material culture and when it cannot. We find that CT is a useful framework for understanding variation in artifact form and change over time (i.e., evolution) and hope to bring this approach to a wider audience. CT provides an explicit quantitative framework for modeling the evolutionary process, allowing researchers to generate specific and testable hypotheses about material culture change.

Cultural transmission past and present

A common misunderstanding about evolutionary studies in archaeology is that "common descent" is somehow equivalent to biological reproduction and/or that "selection" is held to mean that the individuals making those artifacts did not survive. Although these notions may have characterized *some* previous evolutionary approaches, in our view they are outdated and not very relevant in the application of cultural transmission theory in archaeology. Common descent in CT merely refers to the notion that information about material culture is passed between individuals and that similarity in artifact form may be a product of information ultimately coming from the same source. There is nothing about genetics or individual survival rates in such a model.

CT has been implicit in many models in anthropology and archaeology. For example, 19th century anthropologists in Europe, such as Leo Forbenius and Fritz Graebner, took the presence of similar cultural traits in distant areas to reflect interaction and transmission of information between populations. However, it was really in North America where notions of transmission became elevated to a cohesive method of analysis. Franz Boas (1896, pp. 3–4, quoted in O'Brien and Lyman 2002, p. 229) provided a general algorithm for studying historical relatedness: The closer people lived to one another "the greater the number of common elements; the farther apart, the less the number" and "similarity … is more likely due to dissemination than to independent origin." Later he suggested that most of the cultural inventory of a society was the cumulative result of "diffusion" from neighboring cultures (Hatch 1973).

Archaeologists were quick to borrow such ideas to study the archaeological record (e.g., Holmes 1886; Kroeber 1916; Petrie 1899). Similarity in artifact forms over time and space was commonly explained by reference to the diffusion of ideas and information. Thus, Kroeber (1940) considered how small errors in such diffusion affected the distribution of culture-historical types over space and time.

As used by these anthropologists, diffusion was considered a general mechanism by which information was passed (or inherited) across and between populations. Such models were influenced (at least metaphorically if not more directly) by Darwinian evolutionary theory. In the 1950s and 1960s, as diffusionism fell out of vogue, anthropologists began using the word transmission to refer to this concept. Indeed, later anthropologists such as Koppers (1955) use the terms diffusion and transmission almost interchangeably.

Modern CT theory is ultimately a derivative of such diffusion theory; however, there are some important differences between modern CT and diffusion and culture history. While culture historians lacked an explicit theoretical basis and instead made their arguments based on a series of empirical generalizations (Lyman et al. 1997), CT today derives from a much more structured theoretical model, specifically Darwinian models of evolution. Thus, early and mid-20th century diffusion models were focused on the "culture" as a unit of study, and ideas were perceived as being diffused in and out of groups of people who comprise sets of bounded entities. Darwinian theory, of which modern CT is a part, is based more on the actions and decisions of individuals. Moreover, while diffusionists like Boas and Kroeber were interested in change, they were less interested in rates of change, rates of error during transmission, what conditions might foster greater or slower rates of error, different transmission mechanisms, and how diffusion could inform more generally on prehistoric cultures. For most culture historians, diffusion remained a sufficient explanation to account for similarity in the absence of the movement of people (i.e., migration) or goods (i.e., trade) (O'Brien et al. 2005). As a result, modern CT models are generally more rigorous in their definition and more quantitative in their application.

Modern cultural transmission defined

Fundamentally, CT consists of the recognition that culture constitutes a second (in addition to genes) mechanism by which inheritance occurs. In the biological sciences, CT was introduced to account for similarity in behavioral, as opposed to morphological, traits in animals, for example, to explain variation in birdsong (e.g., Bonner 1980; Slater and Ince 1979). Thus. in many species of birds the series of notes individuals sing is not "instinctive" (i.e., determined by genetic information), nor is it entirely individually learned (i.e., through experimentation to see which songs are most effective at some task), but is instead learned from others in the social group. Empirical evidence now shows that many animals acquire portions of their behavioral repertoire via such social learning (e.g., Bonner 1980; Heyes and Galef 1996; McGrew 1992; Nishida 1968; Rendell and Whitehead 2001; Wrangham et al. 1996). Biologists have recorded instances of social learning among dolphins (e.g., Krützen et al. 2005), orca whales (e.g., Ford 1991), primates (e.g., Biro et al. 2003), elephants (Poole et al. 2005), fish (e.g., Brown and Laland 2003), and birds (e.g., Fritz and Kotraschal 1999; Grant and Grant 1996; Lynch 1996). The study of socially learned behaviors within an evolutionary framework has spawned an exciting new field within the ecological and biological sciences.

Humans take social learning to an extreme, and, not surprisingly, anthropologists have been active in the development of CT theory (for foundational works, see especially Boyd and Richerson 1985; Cavalli-Sforza and Feldman 1981). Indeed, anthropologists were among the first scientists to apply quantitative evolutionary models to nongenetic inheritance systems (e.g., Campbell 1965; Cavalli-Sfroza and Feldman 1973; Richerson and Boyd 1978). Given the dominance of culture in the generation of human behavior, application of CT theory provides a powerful means for linking measures of behavioral similarity and claims about historical relatedness. This includes studies of material culture, which is why CT has much potential for archaeological studies.

CT acts to decouple information transfer from biological reproduction and allows information to be continually passed from one organism to another through social learning. This allows for a very different type of evolutionary process to take place because the results of individual learning (i.e., behavior modification) can be transmitted, *in the modified state*, to other individuals. Through individual learning and CT, organisms can continually acquire, modify, and pass on modified information. Thus, the process of CT is fundamentally based on the interaction of both individual experimentation (i.e., innovation) *and* social learning (i.e., copying). Neither of these processes can operate in isolation to produce the impressive array of cultural behaviors humans exhibit, including material culture.

CT can create patterns in behavioral traits that are distinct from behaviors controlled and transmitted genetically. Behaviors governed by genes (i.e., instincts) can only be replicated with the rest of the instructions to recreate the biological form. As a result of the way in which humans biologically replicate through sex, the entire genome composed of different traits is transmitted as a single unit, a mix from father and mother directly to offspring (i.e., vertical transmission), though it turns out vertical genetic transmission (GT) is only the norm in complex higher organisms (for discussions of nonvertical GT, which turns out to be quite common among simple organisms, see Woese 2000, 2004). Cultural information is not part of this replication and is not limited to such episodic replication. Nor is it constrained in terms of the amount of information that can be transmitted and the direction it is passed (e.g., vertical, horizontal, oblique). Instead, cultural information may consist of a single trait from a single individual, the average of a trait in a group of individuals, the modal trait in a population, or any other combination from any set of models. We also can acquire information as traits, sets of traits, or simply as rules on how to acquire additional traits or rules. There are few limits to the structure of information inheritance in CT. As a result, behaviors transmitted culturally have the potential to evolve (i.e., change) quicker than those passed on genetically. This allows organisms to respond more quickly to environmental changes than do hardwired (i.e., genetically controlled) responses (Boyd and Richerson 1985, 1995). Ultimately, this feature of CT provides the means by which humans have accumulated a large and complex suite of cultural traits (Basalla 1988; Boyd and Richerson 1985, 1988; Cavalli-Sforza and Feldman 1981; Durham 1976; Feldman et al. 1996; Henrich and McElreath 2003; Lumsden and Wilson 1981). In sum, GT and CT processes operate in different ways, on different types of information, and need not be coupled. Genetic and cultural evolution may follow quite different and independent pathways.

Thus, for the study of CT it is useless to ask whether a single pattern is *the* true pattern for a group of cultural units. Multiple patterns will generally characterize CT (and, actually, GT when studying simple organisms). This means that methods that are constructed to work when vertical transmission is the norm, such as cladistics, apply only in situations where information tends to be constrained and forms regular physical packages, and there is limited potential for horizontal transfer. This means that when we study cultural variability, our analyses should include *more than one* measure of relatedness, each valid but representing different information pathways. An individual, for example, may be more similar to one group when measured using one attribute (e.g., hair style) and more similar to another when measured along a different attribute (e.g., pant length, shoe style). As a result, in some cases cultural variability may lack distinct groups with clear boundaries and cohesive internal information (e.g., Lipo 2001a; Lipo et al. 1997; Palmer and Wright 1997; Palmer et al. 1995, 2005), though such groups can clearly form (e.g., McElreath et al. 2003).

Finally, it also should be clear that not all similarity in cultural behavior necessarily indicates historical relatedness. People may independently evolve a similar behavior. This is referred to as convergence in evolutionary studies. For example, pottery emerges at different times and places to solve similar needs (i.e., food processing, storage) given similar kinds of resources (e.g., clay, water, heat sources). Populations have repeatedly found baked clay to be a highly efficient solution for the creation of watertight and fire-resistant vessels. Even forms of decoration can be highly convergent, as Meggers et al. (1965) found in their comparison of Jomon and Ecuadorian pottery. Many other kinds of cultural convergences are likely to exist, so we cannot take all measures of similarity to indicate the presence of CT between entities. Distinguishing between instances of historical relatedness and convergence in archaeological studies can be difficult and will form an important realm in future evolutionary studies.

The locus of replication

One component of CT that is relatively unexplored is just where and how replication takes place. The lack of attention in this area leads to fairly simplistic notions of traits moving from individual to individual with frequencies that are driven only by their prevalence in the population. In GT, it has become clear that genes cannot always be treated as independent traits. Such models have been labeled as "bean bag genetics" (Mayr 1959), with the idea that traits can be sorted independently, like beans in a bag. Biologists have found that genes often interact with each other in complex ways (De Winter 1997).

The same sort of understanding must be applied to the study of cultural variability. Gabora (2004), for example, notes that the locus of cultural replication is in the minds of individuals. Minds are more than simple "bags" that hold traits but complex webs of algorithms and rules for acquiring and especially sorting information. Gabora calls these algorithms a "worldview," an outlook similar to that of Sperber (1996). As a person receives cultural information, it is filtered through their worldview, where it is assimilated and related to all existing information before being stored and later recalled. Although strongly shaping the kinds and rates of information acquisition, worldviews are not static entities but constantly change. Gabora suggests worldviews are initially learned from parents and close relatives but over the course of a lifetime are constantly being transformed as new information and new rules are acquired. Thus, the worldview not only transforms incoming information but is transformed itself to accommodate new information and is itself transmitted culturally. Information filters are not only cognitive, such as the worldview, but also biological (see discussion in Eerkens 2000; Eerkens and Bettinger 2001). For example, the human eye and ear filter out most wavelengths, focusing only on those that are within a certain range (i.e., visible or audible).

A number of hypotheses can be derived from this perspective. First, we expect that individuals living in similar cultural, social, and physical environments will tend to acquire similar worldviews. As a result they also may acquire similar kinds of behavioral traits, including material culture. This may help explain why we see similar material culture among members of a particular population. A second hypothesis is that CT may include not only information about traits but also rules about how/when to acquire traits as well as rules about how/when to acquire new rules. Each of these dimensions can potentially vary independently, but there will be a complex interaction between each kind of algorithm. This means that information may change (i.e., evolve) within a population at dramatically different rates. Third, we expect that the set of rules that compose the "worldview" will be cumulative because they build on one another. This aspect of transmission and cognition may help explain why material culture tends to evolve in a continuous fashion, each innovation building on previous ones, rather than including completely new artifacts and technologies (Basalla 1988).

Because CT is a separate inheritance system that governs behavior, CT can easily account for seemingly "maladaptive" traits that spread or even come to dominate within the range of things people do. As long as there are processes acting to increase the number of times a piece of cultural information is transmitted, such as indirect bias or piggybacking on other information, and this information affects behavior, the behavior can increase in frequency within the population. Indeed, CT can help spread behavior-governing information that can override behaviors governed by GT. For example, despite fairly strong genetically controlled instincts to eat, CT can explain why a behavior like anorexia may spread within a population (e.g., worldviews pertaining to a certain body image). Runaway processes and/or interactions with other behavior-governing processes can take these behaviors to extremes, even leading to death.

Within the CT model, change in behavior comes about through a range of sorting and filtering processes that can be, but do not have to be, independent of genetically controlled behaviors and/or environmental change. How well the historical signal of cultural transmission is preserved, particularly over long periods of time, is unknown and surely varies from context to context. The fact that culture historical methods are able to track historical continuity and change seems to suggest that a significant amount of information is preserved in some way and is coherently passed from individual to individual through populations over relatively long periods of time. Consequently, for this article we assume that at least *some* information is transmitted between individuals and that this information is subject to modification before being retransmitted to others either through copying error, filtration through worldviews, or purposeful "innovation." As a result, the information that is transmitted is subject to evolutionary forces. We suggest further that at least some of this information stays relatively intact over archaeologically relevant periods of time. We return to this issue in the closing comments.

Cultural "information"

A second component of CT that needs additional study is the "information" itself that is argued to be transmitted between individuals. Unlike DNA, which is physically passed from person to person in GT, no such empirical entity is known for CT. While we know something has happened after the fact, we have no direct way of "seeing" transmission. There is no physical "chunk" of material that is passed from individual to individual. The lack of a physical expression, however, does not imply that nothing is passed between individuals. Just as in GT, *information* is replicated (Cloak 1975; Cronk 1999; Dawkins 1976, 1982). In this sense, transmission is about the information exchanged between individuals at whatever scale and using whatever physical means (chemical, molecular, sound, or light) is available.

While the absence of a single physical entity is often held to be a key distinction between cultural and genetic transmission, the distinction is far from clear. Biologically, there are a variety of physical entities that carry and transmit information between individuals, including DNA, transfer RNA, and proteins. In the same way, CT makes use of a variety of physical mechanisms that result in the transmission of information. Thus, fundamentally, there is no distinction between GT and CT; each system simply passes information using different ways of coding. It is more productive to conceive of a general case in which genetics, culture, language, and the like are simply versions of generic inheritance systems, structured means in which information is passed between sources and destinations. These systems differ greatly in their implementation, dynamics, and degree of fidelity (i.e., copy error), but this is irrelevant to their information-theoretic structure.

This information-centered view has several consequences. First, the physical forms of transmission are bound to be of a variety of sizes and scales. Although each kind of transmission system has different empirical properties, there are no boundaries on the types of physical entity that can carry information. This is true for cultural *and* genetic forms of transmission. Second, we must keep the physical package separate from the information being transmitted. Genes, in this view, are best conceived of as *measurement units* that are constructed for purposes of making measurements. Genes are not "things" that are found discretely in nature. The same is true for any unit we might conceive of for CT. We are not interested in the physical package or set of physical packages of cultural information but rather the structure, content, and ultimate effect on observable phenomena like material culture.

In terms of units of measurement, the lack of a single empirical entity means that we have to define one. We cannot possibly "find" a unit of CT because information is conceptual by definition. We can, however, *measure* information. The need for an explicitly defined unit was pointed out by Osgood (1951) but has been generally ignored in anthropology except for some culture historians (Brew 1946; Krieger 1944; Phillips et al. 1951; see also Dunnell 1971, 1985; Lyman and O'Brien 2003; Lyman et al. 1997). Although there are no agreed-upon empirical units of CT, we can build a unit for measuring CT. For example, Pocklington and Best (1997, p. 81) define CT units as "the largest units of socially transmitted information that reliably and repeatedly withstand transmission." This definition makes it clear that CT units are measurements of the *effect* of transmission on variability, not a physical package of something. In addition, we can also recognize that many of the units we have used in anthropology also have the potential to be understood as CT units. Culture-historical types, for example, are simply one kind of unit for measuring CT (Lipo 2001a; Lyman and O'Brien 2003).

Evolution, or change over time, in the CT model is produced by the addition (i.e., invention or modification), removal (i.e., winnowing or selection), and differential transmission of behaviors or artifacts (i.e., cultural variants). Because variation is the raw material upon which evolution operates and CT processes directly affect variation, it stands to reason that CT strongly affects the course of evolution. Thus, to understand evolution we must understand these transmission processes.

Factors affecting transmission

In this section we describe in greater detail specific CT models and some of the factors involved in determining the outcome of different processes. What is important for archaeology, in most cases, is not the ability to see and reconstruct each and every transmission event but rather to explain patterns in material artifacts as the result of CT operating in different ways under different circumstances.

Transmission processes vary in terms of their content, context, and modes of presentation and acquisition. These dimensions are not independent but interact during transmission and contribute to the central tendency (i.e., average, mode, median) and especially dispersion (i.e., standard deviation, range, coefficient of variation) of a behavior as it is transmitted over many generations. Transmission works on both the originating (i.e., source of information) as well as the recipient side (i.e., the destination of information) as individuals acquire, store, recall, replicate, and materialize this information. We confine most of our discussion to the transmission of material culture, because this is where the majority of archaeological applications lie.

Content

Content refers to the actual information that is being transmitted between individuals. Such "information" has been referred to by some as memes (Dawkins 1976) and culturgens (Lumsden and Wilson 1981); however, to make it clear that there are no empirical units of transmission, we prefer to simply use the term "cultural information." We argue that the content of what is transmitted has direct implications for the resulting variation and diversity in material culture. Content includes, but is not limited to, the complexity of the information being transmitted, the form in which it comes, the repetitiveness with which the information is presented, and how the information is structured.

The complexity of information being transmitted impacts error rates during storage in the mind of the recipient as well as during materialization of this information as it is recalled. Here we define complexity of information as the length of the description of its regularities (Gell-Mann and Lloyd 2003). The more complex information is, the longer it takes to describe its properties whether done mathematically, pictorially, or verbally. For evolutionary modeling, the complexity of information is important because complex information is subject to greater copying error than simple information, especially in preliterate settings.

The form of information (i.e., written, verbal, visual) also affects evolutionary processes. For example, complex information transmitted through written instructions has lower rates of error than if it were transmitted verbally or if the recipient is able to only visibly watch someone perform an activity (without receiving insight from the performer about those actions). The various human sensory systems are different in their accuracy, hence the propensity to produce error during replication of cultural information (see Eerkens 2000; Eerkens and Bettinger 2001; Eerkens and Lipo 2005). Thus, relative to the magnitude of the incoming signal, the human visual system is much more accurate than the auditory system (Coren et al. 1994; Norwich 1983; papers in van Doorn et al. 1984). It stands to reason that verbal instruction alone results in high error rates. Visual instruction alone results in slightly lower error rates, and visual reinforced with verbal (and/or writing) is much better. However, such an argument needs to be tested with ethnographic field data.

Similarly, the repetitiveness of the information being transferred also affects error rates during replication. Information that is highly repetitive is more likely to be materialized with less error than information that is singular. This is partly why written instructions are less subject to copying error than either verbal or visual copying, that is, because they can be consulted over and over as desired by the replicator of culture. Similarly, a music student who repeatedly hears a musical piece produces fewer errors when replicating the music than a student who has heard it only once. Again, we are not aware of any research in anthropology that examines this topic and it is difficult to state the precise relationship between repetition and error rates in CT. Engineering studies might provide additional guidance here because there is great interest in how complexity, repetition, and other factors affect the transmission of digital information and mechanical energy (Shannon and Weaver 1949; for recent work see Combet et al. 2005; Cover and Thomas 1991; Sheng-Wei et al. 2004; Wang et al. 2004). However, we do not review the engineering literature here.

Finally, it also is clear that the structure of information affects how it is transmitted. In a series of controlled experiments, Mesoudi and Whiten (2004) showed that social information loses detail (“low-level information”) but may gain high-level structure as it is transmitted between people verbally. In other words, people in their experiments tended to leave out detail that was considered “common knowledge” but added higher-level summarizing statements instead. For example, during the transmission of a story about two hypothetical actors going to a restaurant and performing various specific activities (e.g., open a menu, look at menu, call waitress, place order, eat, ask for bill, bill arrives, take out wallet, leave money), information tended to get summarized into mid-level actions (e.g., order food, eat food, pay bill). Later transmission of these mid-level actions tended to summarize them into a single statement that the two actors simply went to a restaurant. Additional experimental work carried out by Mesoudi (Mesoudi et al. 2006) suggests that social gossip is transmitted with greater accuracy than similarly structured but nonsocial information. Washburn (2001) has undertaken similar experimental studies, although with visual information, by asking undergraduate art students to reproduce images from both familiar and unfamiliar cultures. She found that the overall structure of the images was more accurately reproduced than elements about detail. Furthermore, cultural background played an important role in the accuracy of reproduction; the greater the familiarity of the culture from which the image was drawn, the greater the accuracy in reproducing structure and especially detail.

These studies demonstrate that the content of information, mediated by the cultural context (i.e., “worldview”) plays an important role in structuring how individuals see, interpret, remember, and reproduce knowledge. Furthermore, it suggests that structure in material culture design may be more accurately transmitted than details about design. These findings have implications for where archaeologists should expect the greatest degree of variation and change in material culture over long periods of time. Specifically, overall structural aspects about technologies should stay relatively unchanged, although details may fluctuate greatly, especially when the details are many, complex, and nonrepetitive. As well, immigrants to communities, for example, through exogamous marriage, may generate greater amounts of variation in reproducing local material culture than natives, especially in structure.

Context

Context refers to the social and physical setting in which cultural information is transmitted and has not been extensively studied by anthropologists either. On theoretical grounds we hypothesize that the physical and social context of transmission can mediate or alter the content of what is being transmitted. For example, transmission of verbal instructions within a noisy environment (e.g., a bar) could affect the clarity of the information, causing increased chance of error as opposed to a quiet setting (e.g., a classroom). As well, the social context may affect the outcome of transmission events. Among youth, information transmitted from a pop icon or "prestigious" individual may be regarded with greater esteem, hence remembered and potentially retransmitted with greater accuracy, than information from a peer or underling (Henrich and Gil-White 2001). Information is also likely to be transmitted more accurately when it is invested with authoritative credibility or is regarded as private or secret rather than public (Rowlands 1993). Likewise, under some conditions individuals may pay closer attention to information coming from someone more like themselves than someone different (Schlag 1998).

In one of the few examples from cultural anthropology, Barth (1987, 1990; see also Whitehouse 1992) compared how ritual information was transmitted in two different regions, southeast Asia (Bali) and Melanesia (inner New Guinea). In particular, he examined the differential effects of transmission between "gurus" or "conjurors" and students or initiates, that is, between people who possess knowledge and those seeking it. He found that the context in which this information was transmitted greatly affected variability in how it was remembered and subsequently retransmitted. Information transmitted only once during late-night episodes highly shrouded in secrecy and mystery, sometimes under the influence of psychoactive substances, tended to be characterized by high rates of error and resulted in greater variation over time. On the other hand, information transmitted in formal settings where it is often repeated and the content is highly valued is characterized by much lower rates of error.

Linguists have been more active in this field. Labov (1972, 1994) studied dialect variation on Martha's Vineyard, an island off the New England coast of North America. Profession, desired future profession, and attitudes toward living on the island versus the United States mainland greatly affected the dialect individuals chose to imitate and utilize in everyday speech. Thus, social context influenced how individuals copied and acquired language and dialect. On a related topic, some linguists and epigraphers have explored how the presence of a writing system affects the rate of language evolution (see Fromkin and Rodman 1997; Houston et al. 1998; Hruby 2002; Trask 1994), where writing seems to promote a more conservative rate of change within spoken language.

While there has been more theorizing about the effects of context rather than content on transmission, there have been few ethnographic tests of these models (e.g., Barth 1990; Labov 1994). It is not yet clear if there are strong cross-cultural patterns in how context affects transmission processes that we might apply to archaeological studies. Thus, it is possible that artifacts transmitted within ritual contexts had conservative rates of change compared to those used to mark age or language groups, but lacking repeated and controlled field-based studies, the magnitude of such differences is difficult to estimate. Moreover, archaeologists are presented with the additional issue of trying to reconstruct such contexts and how they applied to the transmission of information about material culture. Clearly, much research remains to be undertaken in this realm.

Mode

Mode refers to the process by which individuals transmit and acquire information. Mode of transmission specifically focuses on the details of the cognitive rules that individuals use to acquire information, although it is unclear if these rules are themselves culturally transmitted or inherited genetically. Such rules are incorporated within and affect the "worldview" of individuals. While we can explain some variability through models of random copying in which individuals choose traits due to chance encounters (e.g., Bentley 2005; Bentley and Shennan 2003; Bentley et al. 2004; Hahn and Bentley 2003; Herzog et al. 2004; Lipo 2001a; Lipo et al. 1997; Neiman 1995; Shennan and Wilkinson 2001), not all variability can be explained in this way. Individuals have a variety of rules by which they accept information, and each of these rules has the potential to structure the pattern and distribution of traits in a population. Indeed, recognition that there is variation in how people accomplish this essentially led to the development of CT as a formal field of investigation in anthropology, and as a result we know much more about how the mode of transmission affects the CT process as a whole. Significant mathematical modeling and computer simulation has been done in this area (e.g., Bentley et al. 2004; Boyd and Richerson 1985, 1987, 1995, 2002; Cavalli-Sforza and Feldman 1981, 1983; Eerkens and Lipo 2005; Hahn and Bentley 2003; Henrich 2001, 2004a; Henrich and Boyd 2002; Henrich and Gil-White 2001; Henrich and McElreath 2003; Lipo et al. 1997; McElreath et al. 2003; Shennan 1989; Soltis et al. 1995). In fact, many people equate CT with the study of mode, often ignoring or paying minor attention to content and context.

The mode of transmission can vary depending on the number of people involved, the direction of transmission, any biases that exist in how information is acquired, and how information is packaged. The number of people involved can include processes referred to as one-to-one, many-to-one, one-to-many, and many-to-many transmission. One-to-one includes simple transmission between two individuals, many-to-one includes transmission of information between, for example, a panel of experts and a single student, one-to-many includes a teacher passing on information to a classroom of students, and many-to-many includes a panel of experts teaching a classroom of students. As Cavalli-Sforza and Feldman (1981) and Boyd and Richerson (1985) have modeled, these different modes of transmission can have dramatic effects on the rate of evolution of cultural information. For example, many-to-one transmission tends to slow the rate of change relative to one-to-many transmission (MacDonald 1998, p. 230; Shennan 2002).

In addition to the number of people involved, transmission also can vary depending on the direction in which information is passed. As mentioned, in CT information can be passed between any two individuals, including peers (horizontally), unrelated individuals who are of the previous generation (oblique), from children to parents, or can even skip generations, for example, between grandchildren and grandparents. These pathways are on top of the one-to-one, many-to-one, and one-to-many transmission modes discussed above. The direction of CT affects not only rates of change in culture but also interindividual and intersocietal variation in cultural practices (Boyd and Richerson 1985; Shennan 2002). For example, vertical transmission results in low variation within household lineages but high interhousehold variation and relatively slow rates of change. Horizontal transmission tends to minimize interhousehold but increase intrahousehold variation and *can* result in much more rapid rates of change over time within households.

CT also can be biased by decisions individuals make about information acquisition. Such biases often have been given specific names such as conformist or prestige-biased transmission. The essential character of biased transmission is that information may come from different sources within a population in spite of being transmitted in a similar direction and involving the same number of people. Henrich (2001) suggests that such biased transmission has been the dominant form of CT among modern humans. Biased transmission may save an individual time and effort otherwise expended on experimentation to find a successful cultural trait such as an efficient tool for hunting or a clothing style that confers elevated status.

Conformist transmission, a particular type of frequency-dependent transmission (Boyd and Richerson 1985), is thought to be advantageous when gathering all the information needed to make a well-informed decision (i.e., experimenting) is time consuming or socially costly, or when such information is complex or impossible to acquire (Bikhchandani et al. 1998; Henrich and Boyd 1998, 2001; Smith and Bell 1994). In essence, conformist transmission is a many-to-one system but with a particular type of bias, where the "many" represents those individuals possessing the modal or average behavior. Another frequency-dependent biasing mechanism is rarity (or pro-novelty) biased transmission. Prestige-biased transmission operates on a similar principle, except that certain prestigious individuals, rather than the masses, are assumed to have access to (or have experimented to acquire) superior information (Barkow 1975; Rogers 2003; Schlag 1998; see especially Henrich and Gil-White 2001). Exploitation of this principle is common among today's advertisers (e.g., "Be like Mike"), where prestigious individuals such as movie stars and professional athletes are shown using certain products. Presumably, people are apt to copy such individuals because they believe their social success stems, at least in part, from the types of commercial products they use. Though there are other biasing mechanisms (see Henrich and McElreath 2003), conformist and prestige-biased transmission are the most widely discussed and have seen the greatest application in archaeological research (see below).

Finally, the mode of transmission can vary depending on how information is packaged. In some cases, cultural information may be transmitted because it "hitchhikes" with other information (O'Brien and Lyman 2003). For example, a person copying a potter to produce cooking containers may copy not only the shape of the pot but also the construction method and exterior painted designs as part of an information package because they are unsure which attribute makes a superior cooking pot. Such transmission results in a high degree of covariation between different attributes, empirical signals that are left behind in the archaeological record. In other cases, the painted designs may not be transmitted as part of the information package, thereby separating shape from construction method and design. Such hitchhiking is somewhat analogous to "junk DNA" in GT (e.g., Doolittle and Sapienza 1980; Gibbs 2003; Orgel and Crick 1980), where pieces of genetic code are able to insert themselves onto the genome and get replicated. Boyd and Richerson (1985) refer to the hitchhiking process in CT as "indirectly biased transmission." Prestige-biased transmission may often be characterized by such information packaging. As well, complex and composite technologies may often be transmitted as single entities rather than different attributes of the technology being transmitted piecemeal.

Discussion

The above review is necessarily brief and simplified because of space restrictions. Readers interested in more detail should consult some of the primary references. What is clear, however, is that different combinations of the content, context, the number of people involved, the direction of transmission, biases, and information packaging present a bewildering array of possibilities for CT. These relatively unrestricted (i.e., flexible) and interacting pathways by which cultural information can be transmitted results in extremely complex evolutionary processes, making it difficult to intuit results of long-term evolutionary change. Combined with the difficulty of actually observing CT over extended periods of time, these complexities have hindered advance in CT research.

Most CT studies, particularly computer simulation and mathematical modeling, tend to focus on only certain aspects of the transmission process in isolation, especially mode and various biasing mechanisms. Such research has been valuable in showing the potential effects of different attributes of CT on the average, variance, direction, and rate of change of material culture over long periods of time. Yet a major gap in our understanding of CT in practice is how all these different variables interact in real-world situations. This is an arena where archaeology can potentially contribute much, given the concern with long time scales and evolution. However, this will involve a theoretical shift from using CT to explain the archaeological record to using prehistoric artifacts to inform on CT. In other words, it will come from building CT theory based on archaeological research.

The models we have described above do not explicitly include gender, power relations, class, or other aspects of social processes that critics of evolutionary approaches often point out as failures of the paradigm (Dobres 2000). This is not a failing of CT but rather of scholars who have done research on CT. The structural framework of CT could easily include gender, class, and other issues that serve to cause transmission to be filtered, modified, or biased. As discussed above, these kinds of algorithms are part of our variable, built-in, and heritable worldviews, that is, the cognitive and inherited rules that structure how information is acquired and sorted. For the most part, practitioners have not included these aspects within their CT models, and this also is a potential direction for future CT research.

Applications of cultural transmission to the archaeological record

A body of theory is only as good as its ability to help us understand and provide new insights into the phenomena we attempt to explain. Among most archaeologists there has always been an implicit notion of the transmission of cultural information. As mentioned above, similarities in artifact styles that were used to track culture-historical types over time implicitly assumed that material culture was passed down over generations with only slight change (see Lyman 2000; Lyman and O'Brien 2000; Lyman et al. 1997; O'Brien and Lyman 1999, 2002). More formal models of CT, such as dual inheritance theory set forth by Boyd and Richerson (1985), have seen only sparing use in archaeological research. The paucity of informative archaeological case studies and the lack of "reference to people as intentional agents" has caused some, such as Mithen (1997, p. 68), to reject the theoretical paradigm outright. Similarly, Schiffer (2004) does not believe CT is a productive way of studying variability in human behavior. Even Dunnell (1992, p. 214), a prominent evolutionary archaeologist, has characterized dual inheritance as "a theory in search of an application."

Theory is evaluated on the basis of whether it is logically coherent and complete (i.e., dynamic sufficiency) and helps explain observed phenomenon in the world (i.e., empirical sufficiency) (Lewontin 1974). In the case of CT theory, we believe that the overall framework is robust because it is a comprehensive logical system for explaining information sharing between individuals and across populations. The statement by Mithen (1997) that people are somehow robotic receivers and transmitters of information is clearly not an accurate portrayal of how transmission works as described above. Individuals (i.e., actors) receive information and intentionally act upon it (e.g., ignore it, choose from whom to accept it, modify it, experiment with it). The degree of empirical sufficiency is less clear. This is primarily due to a lack of application in archaeology, as noted by Mithen (1997) and Dunnell (1992). This lack does not necessarily mean that we cannot apply CT models and generate useful and falsifiable accounts of the archaeological record. Rather, it points to a limited number of attempts at application, something we believe is beginning to change.

In the discussion below, we highlight studies that go beyond implicit notions of transmission (i.e., simply recognizing that cultural material is shared). Instead, our focus is on how researchers have begun to examine concepts such as content, context, and mode of prehistoric transmission to profitably explain structure in the archaeological record. We review studies that use the models of transmission as an active and formative process rather than simply as a context within which to identify artificiality (i.e., the results of human behavior) or culture (i.e., the results of transmission). This review underscores two issues. First, CT can be applied to the archaeological record in constructive and informative ways. Second, we still have much modeling, data collection, and hypothesis testing to do to maximize the value of CT.

Content

Most archaeological applications of transmission theory have focused on the content of information. Of these applications, one of the most prominent is the analysis of "stylistic" variability (e.g., Lipo 2001a; Lipo et al. 1997; Lyman and O'Brien 2000; Neiman 1995; Shennan and Wilkinson 2001; Teltser 1995). The study of stylistic variability has a long history in archaeology that begins with earliest emergence of culture history (Kidder 1915; Kroeber 1916, 1919; Nelson 1916; Spier 1917). As a means of explaining the archaeological record in terms of time and contact among populations, style has an inherent link to cultural transmission. Although archaeologists came close to making this link explicit (e.g., Rouse 1939), there was initially little attempt to explain why stylistic classes behaved as they did in the record. In the view of culture historians, style was considered to be anything that worked in the construction of seriation, and evaluation procedures were trial and error (e.g., Krieger 1944). The advent of the new archaeology added much variety to the discussion of style (e.g., Conkey and Hastorf 1990). Overall, however, the concept remained much the same. Archaeologists such as Longacre (e.g., 1970), Hill (e.g., 1966, 1968), and Deetz (e.g., 1965) used the same notion of style as did the culture historians (e.g., Ford 1935, 1936; Kidder 1915, 1917; Nelson 1916), though they made a point of claiming to do otherwise. Despite the apparent variation in their discussion of style, most of the new archaeologists share the notion that style is something that exists independent of an observer, that is, it is empirical.

The explicit connection of stylistic variability to CT emerged in 1978 when Dunnell introduced a theoretical basis by which the *concept* of style could be explained. The critical part of this change is recognizing style simply as a conceptual tool for explaining the empirical world rather than a physical entity *per se*. Using a framework grounded in the principles of Darwinian evolution, Dunnell (1978, p. 199) defined style as "those forms that do not have detectable selective values." Stylistic traits, he argued, are best explained as *neutral* traits.

The notion of neutrality helps sort out the empirical part of style from the theoretical. While our common sense suggests that there is "style" out there in the world we observe, we can see that the notion of style has two aspects. As a concept it is a means by which we measure and explain variability, specifically heritable variability that we can explain without invoking the sorting role of natural selection. As a phenomenon, one way in which we can account for "style" is through the concept of neutrality. Importantly, neutrality need not be the only way to explain a phenomenon we might common-sensically call "style." All empirical entities can be described and explained in an infinite number of ways. Neutrality is just one of the ways we can account for a phenomenon, specifically through the conceptual framework of heritable variability without selective differences. Both aspects of style—the concept and the phenomenon—can be directly related to CT.

Although this was first recognized in 1978, the conceptual linkage between style and CT has been slow to spread. In part, this is because Dunnell's original configuration of style is flawed. In the earliest formulation, stylistic attributes were conceived as those without selective values. We can readily appreciate, however, that all physical attributes that we can observe and account for in terms of style must have had cost in terms of manufacture. This means that these attributes must have the *potential* to be sorted by natural selection, thus blurring the definition of the term style.

The concept is salvaged if we change our focus from the lack of selection for characteristics that mark stylistic traits to those that are simply *equivalent* or instances where variability represents equal cost alternatives. In the case of pottery design, for example, incisions and punctuates each involve cost during manufacture. Potentially, though, each kind of design is equal in terms of performance. The design, therefore, is free to vary independently as long as its replicated success depends solely on transmission. Meltzer (1981, p. 314) suggests that "in many instances, the choice between certain kinds of design elements on ceramics is not a functional consideration, but rather is historically determined and selectively 'neutral,' because there is no inherent advantage between one element and the next. The actual presence of the design, however, has a selective value because that particular design serves to mark a certain individual or group boundary (or whatever other function it may serve)." This formulation means that selection might constrain the *amount* of time spent decorating but not the specific variants of decoration. Choices about decoration are subject to cultural preference and cultural transmission. Style is, therefore, a way of measuring and explaining material culture through the conceptual framework of cultural transmission.

How do we know what kind of variation we need to measure in order to explain the record in terms of style and CT? O'Brien and Holland (1990) argue that engineering studies are a way of distinguishing stylistic from functional traits (see also Feathers 1989, 1990; Kornbacher 2001; O'Brien et al. 1994; Pfeffer 2001; Wilhelmsen 2001). Engineering studies involve the analysis of performance for different alternatives. The smaller the degree of performance difference for any particular function, the more likely the traits will have neutral distributions. This means, however, that studying CT requires at least some control over the selective environment and performance characteristics. Forms of ceramic vessels, for example, might have large performance differences in terms of their ability to transport materials but could well be neutral traits if the ceramics were never involved in carrying. Ultimately, it is how traits behave across space and through time that determine whether we can explain them as stylistic or functional. Bettinger et al. (1996) argue, however, that the evolution of selectively neutral traits will be difficult to differentiate archaeologically from functional ones. Both are patterned in space and time due to the very processes by which cultural information is transmitted. Moreover, apparent structure in the evolution of stylistic traits also can result from hitchhiking with functional traits.

Another key aspect of the focus on style in relation to CT is the recognition of regular patterns that can be generated in time and space. These patterns were described as “monotonic” in terms of their distributions by culture historians and have been noted in prehistoric as well as contemporary phenomena (e.g., Deetz and Dethlefsen 1965, 1971; Harpole and Lyman 2002; Kroeber 1919; Lieberson 2000; Neiman 1995; Phillips et al. 1951). One of the ways in which these robust patterns have been explained is through the use of neutral models, which state that traits are equivalent in term of their cost and performance. This means that in the absence of any rules, information will be acquired randomly.

While this assumption can be falsified, the random copying assumption provides a useful starting place for studying CT. Fundamentally, a random copying model is a *null hypothesis*. Before we can invoke alternative processes shaping cultural variability, we must first determine the degree to which random copying of neutral traits alone can account for our observations. Based on a simple, quantitative model of population genetics, the model of random copying of neutral traits shows significant potential for explaining many forms of cultural change, including fashion, ceramic styles, sherd thickness, dog breed choice, and name choice (Bentley 2005; Bentley et al. 2004; Bentley and Shennan 2003; Hahn and Bentley 2003; Herzog et al. 2004; Lipo 2001a; Lipo et al. 1997; Neiman 1995; Shennan and Wilkinson 2001). In this way, connecting the “style” concept to a larger theoretical framework involved in CT, neutrality, and random copying provides a strong methodological foundation for exploring why particular cultural attributes have distinctive distributions in time and space.

In a now-classic paper, Neiman (1995) simulated the transmission of neutral variants, including the effects of experimentation (i.e., individual learning) on artifact assemblages, to create a neutral model for drift, innovation, and the differential persistence of traits. He then related his findings to measures of ceramic diversity, and the formation of “battleship” curves, with Woodland period ceramics from Illinois. Neiman did not model the context of transmission and only touched on the mode of transmission. He found that measures of diversity within and between ceramic assemblages are strongly affected by innovation rates, horizontal transmission, and population size. Based on comparisons to Woodland period ceramics, he suggested that intergroup transmission was initially low in the Early Woodland period, rose to a maximum in Middle Woodland, and then abated again in the Late Woodland period. His paper formed the groundwork for several later studies of transmission (e.g., Bentley and Shennan 2003; Eerkens and Lipo 2005; Kohler et al. 2004; Shennan and Wilkinson 2001). In particular, many of these later studies borrow Neiman’s expected rate of innovation for “neutral” traits to determine if prehistoric societies were pronovelty (i.e., innovative) or antinovelty (i.e., conformist) in nature.

Building on Neiman, Lipo and colleagues (1997; see also Lipo 2001b; Lipo and Madsen 2000) use ideas from CT theory to model the evolution of neutral traits over time and space. Like Neiman they were interested in how such transmission affects the distribution of traits in time and space and use computer simulation to create null models under different conditions, with particular interest in how horizontal and oblique interaction affect the process of frequency seriation. Ultimately, they compare their results to ceramic data from the lower Mississippi Valley to study how pottery assemblages distributed over time and space can inform on prehistoric interaction. Lipo (2001a) continued these studies to examine how seriation of pottery can map patterns of prehistoric transmission. He examined how hierarchical groups emerged in the Mississippi River valley by looking at spatial and temporal patterns in interaction and transmission. Populations seem to have been structured into cultural lineages that passed on certain neutral styles of pottery manufacture. His study was significant because it added scientific rigor to what were until then assumptions or conjectures about space–time patterns in pottery assemblages.

The exploration of the kind of information that is exchanged through CT also has involved the study of human cognition and its impact on sorting variability. Employing ideas from cognitive anthropology, Mithen (1997, 1998), for example, has argued that the human brain has evolved to efficiently transmit certain kinds of information but not others. In particular, he suggests that the modern brain evolved to solve certain kinds of problems for our hunter-gatherer ancestors, especially those related to foraging, the manufacture and use of tools, and social interaction. As a result, he suggests humans easily transmit information about these things with little error, but have much more difficulty with the transmission of others such as how to buy a car or information about religion. To accomplish the latter requires "cultural support, such as visual symbols and ritual to anchor them in the mind" (Mithen 1997, p. 73). Thus, humans link the difficult information to things they can easily transmit as part of packages. One outcome of this hypothesis is that certain kinds of information will be bundled during transmission, for example, religious ideas with ritual artifacts and social behaviors or information about "gods" with social information about people or the natural world. According to Mithen's argument, the presence of such domain-specific structure within the brain results in strong patterns in covariation between certain kinds of information during cultural evolution. This is similar in structure to the worldviews of Gabora (2000) and the "indirect bias" model of Boyd and Richerson (1985). We are unaware of any subsequent attempts by Mithen or others to test this hypothesis, or even to apply this theoretical approach to the archaeological record.

Context

As among CT theorists and field anthropologists, the context of transmission and how it produces structure in prehistoric material artifacts has not been widely studied by archaeologists. Rowlands (1993) touched upon this topic in a theoretical piece published in an archaeological journal. Unfortunately, he did not provide an archaeological case study but used only examples from ethnographic and historic material culture instead.

As discussed earlier, an exception is the work of Washburn (2001), who examined the role of cultural background in transmission and reproduction of visual art iconography, though she did not examine in greater detail exactly how this happened. She suggested greater familiarity with the cultural context led to greater accuracy in the detail of reproduced images. A second major exception is the work of Kuijt (2001; see also Kuijt 2000), who examined how community and household ritual affected the transmission of mortuary practices in early agricultural societies in the southern Levant. Through the creation of shared social memory and ritual belief systems within communities, he suggests that information transmitted under such conditions should be characterized by slow rates of change. This, he argued, was the reason skull removal and burial practices remained unchanged for centuries in prepottery Neolithic societies in the Near East.

Finally, Henrich (2004b) has used CT theory to examine the diversity of material culture and technological knowledge under different contexts, specifically different population sizes. By way of a mathematical model, he shows that the effective population size (i.e., the number of interacting social learners) is an important factor in the transmission of complex versus simple material technologies. Henrich finds that complex technologies tend to be lost when populations decrease in size while simple technologies are maintained or even improved. He applies this result to prehistoric Tasmania where rising sea levels cut the island off from Australia sometime in the early Holocene. Henrich ascribes the loss of several major technologies, including bone tools, cold-weather clothing, hafted tools, nets, barbed spears, spear throwers, and boomerangs, to the relatively sudden loss of contact with the population of social learners on the mainland of Australia. Thus, when people use social learning to acquire cultural information, population size will have a fundamental structuring affect on the transmission of that information, one that should be visible in the archaeological record. Certainly there may be other factors that affect the development and/or retention of different technologies, and there may be disagreement with some of the details and results of Henrich's study. However, we view the work favorably, not for what it says about Tasmania in particular (a record we are not familiar with), but because it takes a model derived from CT theory, generates predictions from it, and tests it with data from the archaeological record. If nothing else, the study provides future archaeologists with an interesting model from which to derive predictions and test.

Mode

Far more research with CT theory in archaeology has examined prehistoric modes of transmission. For example, MacDonald (1998) turned to CT to help explain the widespread geographic range of Folsom technologies and conservative rates of change, points, and flintknapping techniques and suggested that knowledge about flintknapping was probably transmitted using a many-to-one strategy. Likewise, Shennan and Wilkinson (2001) also used CT to explain rates of change in pottery technology in Neolithic Linearbandkeramik settlements in the Merzbach Valley of Germany (see also Bentley and Shennan 2003). Building on Neiman's (1995) model for the evolution of neutral variants, they argue that the first inhabitants in the region copied one another fairly closely and carefully, with only slight changes over approximately 100–200 years. The amount of variation generated during this time is in line with what would be expected under a drift model for neutral variants. However, the later Merzbach sequence shows a clear bias toward pronovelty or "anticonformist" transmission. Shennan and Wilkinson argue that individuals sought to actively identify themselves and their pottery wares through the use of unique decoration motifs (i.e., to establish distinct local identities). The apparent use of different variance increasing and reducing transmission mechanisms through time provides tantalizing clues about the social nature of Folsom and Linearbandkeramik societies. Like most good research, these issues raise new questions with testable hypotheses that future archaeologists can address.

CT also has been used to explain the maintenance of group cohesion through common iconography (Kohler et al. 2004) or ritual behavior (Aldenderfer 1993; McClure 2004). Kohler et al. (2004) suggest that conformism, including to material culture, may have fostered internal cooperation that provided villages a competitive advantage in access to the best arable lands, hunting territories, and the like. Aldenderfer (1993) takes these arguments a step further, suggesting that runaway conformist evolutionary processes allow ritual behaviors to become controlled by certain people, leading to the development of rigid hierarchies where key individuals wield great ritual power to extend their prestige and social power.

Still others suggest that changes in the direction in which information was transmitted structures the archaeological record, and hence the prehistoric mode of transmission can be reconstructed based on these signals. For example, Shennan (2001) simulated the effects of transmission direction against population size to derive predictions for the rate of technological change throughout the Pleistocene, finding that both factors had significant effects on the transmission of innovations. Members of larger populations had greater corresponding reproductive fitness levels when innovations were advantageous, a result that was amplified when transmission was predominantly oblique versus vertical. Shennan suggests that the dramatic rise in technological complexity over the last 50,000 years may be a result of increasing population size and/or changes in the mode of transmission. Based on variation measures, McClure (2004) suggests that Neolithic pottery technologies in Valencia, Spain, were transmitted primarily vertically in the Early Neolithic but obliquely during the Late Neolithic. Along similar lines, Jordan and Shennan (2003) use phylogenetic methods to tease apart the influence of horizontal from vertical transmission in ethnohistoric baskets in California, while Tehrani and Collard (2002) use similar methods to examine the transmission of decorative elements on historic Turkmen textiles. Interestingly, while Jordan and Shennan find evidence primarily for horizontal transmission across language groups in California, Tehrani and Collard find that 70%–90% of the variation in Turkmen carpet designs can be explained by vertical transmission, with only minor evidence for horizontal transmission between ethnic groups.

Finally, some studies have examined covariation of archaeological traits as a means for examining the transmission of information packets. Bettinger and Eerkens (1997, 1999) use CT theory to predict that social transmission (versus individual learning) is more important for complex technologies than simple ones when the cost of experimentation is high and will be characterized by higher attribute covariation. They find some support for this conclusion in hunting technologies (i.e., projectile points) from the North American Great Basin, although the strength of covariation varies between different subregions in the Great Basin. On the other hand, in a similar study of projectile points from the American Bottom region, Shott (1997) found only slight support for these predictions. Spencer (1993) weighs in on this issue as well, suggesting that individuals in spatially or temporally varying environments, including variation caused by frequent and unpredictable warfare, are better off using social learning to acquire information. As a result, information is likely to become packaged in such situations. Spencer uses this framework to explain the evolution of leadership positions in chiefdom societies, where leaders are able to package information about their justified elevated status and incontestable power, often through active manipulation of transmission mechanisms.

Discussion

The aforementioned studies show the range of applications of CT to the archaeological record. As is evident, CT theory is gaining at least a small following in archaeological research. Most of the studies cited in the previous sections were undertaken in the last ten years. This growth mirrors development in cultural anthropology, where the rate of publication has accelerated noticeably in the last ten years for studies exploiting or exploring various issues related to CT. In the remaining sections we highlight some strengths and weaknesses of this approach to understanding the archaeological record.

Explanation versus theory building

The vast majority of CT research in archaeology has revolved around the use of CT theory as a means to understand and explain variation and covariation within and between assemblages of artifacts or traits of artifacts. Thus, archaeologists measure patterns in the attributes of artifacts to deduce ancient transmission patterns, which are then extrapolated to make claims about the nature of past societies and what may have prompted individuals to use one type of transmission system over another. For example, societies might be characterized either as employing primarily social learning to transmit information, resulting in higher within-community conformity, or as encouraging individual learning and experimentation. Alternatively, societies might be characterized as using primarily oblique versus vertical transmission. While such differences may represent an alternative social structure and/or ethos and may be interesting to know in individual prehistoric cases, such descriptions are rarely extrapolated to larger interpretive or theoretical frameworks. They are used only to explain the archaeological record of a particular window of time in space. Ultimately, such descriptive studies represent a wholesale and fairly uncritical borrowing of ideas from CT rather than attempts to falsify the theory, as science should strive to do (e.g., Popper 1959).

Few archaeological studies have sought to test the validity of CT theory by deriving hypotheses and comparing them against prehistoric material culture. Even fewer archaeological studies have sought to actually contribute to and build CT theory itself. We are not faulting all or any particular archaeologist here, for this is a challenging undertaking. In particular, it will require that archaeologists control for different aspects influencing transmission, such as content, context, and/or mode. By doing so we will be able to see whether, for example, complex material technologies tend to be transmitted in packages and witness less experimentation than simple ones, or whether immigrants to a region produce greater error in the detail of visually transmitted information than natives.

We believe that controlling for content will be easiest for archaeologists, which is likely why most previous applications have been along these lines. For archaeologists, we constantly deal with the outcome of the transfer of information about material culture in the artifacts we recover. Studying those artifacts and their attributes allows us to track the transmission of information about how to make them. Slightly more difficult will be controlling the social and physical context of information transfer. Although archaeologists are trained to think about context, the main problem here is in the state of CT theory itself. As discussed earlier, little research has systematically addressed the context of information transmission, even in modern settings. Most difficult for archaeologists will be controlling for the mode of transmission, for we cannot directly see transmission events in the archaeological record. Usually archaeologists rely on indirect measures from artifacts themselves to estimate the prehistoric mode of transmission. If we are then using those same measurements to control for content or other factors, we run the risk of running into circularity in our arguments (e.g., controlling content to examine the effects of mode, and then "controlling" for mode to also examine the effects of content). Fortunately, there has been greater research and theory building within anthropology on the mode of transmission, and these processes are better understood. In sum, we think it is time for archaeological research on CT to move beyond primarily description and explanation to the more difficult task of theory testing and building.

Furthermore, while CT clearly affects the shape and size of elements of material culture, especially variability therein, we recognize that invoking CT is just one part of explaining the archaeological record. Observed variability in artifacts and assemblages can also be structured by postdepositional alteration and other nontransmission processes. Fortunately, archaeologists are fairly adept at studying many of these sources of variation, for example, by use-wear studies and postdepositional alteration (e.g., Blackham 2000; papers in Hayden 1979; McBrearty et al. 1998; Olson and Shipman 1988; Schiffer 1987; Skibo 1992). Models have been put forward in archaeology attempting to integrate these different sources of variation into a single model (e.g., Schiffer 1987; Schiffer and Skibo 1997; Schiffer et al. 2001), but these are rarely linked to the framework of CT processes (but see Lipo 2001a, b). We argue that CT should be an integral part of understanding and explaining variation in material culture, particularly when we are interested in examining cross-temporal patterns, and should be actively included in such models.

Central tendency versus dispersion

We believe that a major reason CT has not seen wider application is the continued focus on central tendency in archaeology. Explaining, for example, why decoration motif X accounts for 80% of the pottery at one point in time but is replaced by motif Y later in time or why the dominant technology changes from one form to another, such as pottery replacing baskets, has been a central focus in archaeology. Significantly less time has been spent exploring the dispersion or variation about central tendencies. While the titles of research articles in archaeology suggest that archaeologists are concerned with "variation" in material culture, the focus of such studies often remains on the richness and diversity of different "types" rather than variation within a type or about a mode.

While CT is sometimes relevant to understanding issues concerning central tendency, CT has the greatest predictive power when dealing with variation and diversity. As discussed earlier, CT theory has been quite productive in helping archaeologists explain diversity of artifact types or ideas (e.g., Bentley and Maschner 2000, 2001; Henrich 2004b), especially in terms of the concept of style (e.g., Bettinger and Eerkens 1997; Kohler et al. 2004; Lipo 2001a; Lipo et al. 1997; Neiman 1995; Shennan and Wilkinson 2001). A second equally important but less studied aspect of CT concerns the study of dispersion and changes in dispersion over time (though see Bettinger and Eerkens 1997; Eerkens and Lipo 2005).

As discussed above, various transmission processes produce different patterns in variation, with some such as conformist transmission removing variants from the pool of behaviors (i.e., winnowing away), and others such as experimentation and innovation adding new ones. Such changes can happen with or without changes in central tendency. Thus, CT theory can generate potential explanations about the amount of variation about a mode one can expect to see under different circumstances. Furthermore, CT also has much to say about the covariation of different behaviors, as some processes such as indirectly biased transmission link different traits together as part of inheritance packages. Unfortunately, the documentation of variability and measures of dispersion (e.g., standard deviation, coefficient of variation) and covariation are not systematically reported in archaeological research. To maximize the utility of CT, it is important that archaeologists consistently report and consider the explanatory implications of dispersion measurements as well.

Furthermore, a body of theory that can be used to explain and make predictions about dispersion is a powerful tool for evolutionary studies. If there are factors acting to winnow or trim the margins of such distributions before or during retransmission, the wheels are set in motion for temporal change. If the forces trimming values on either side of the mean are unequal (e.g., smaller values are differentially winnowed relative to larger ones), directional changes in the mode will take place. Similarly, if there are forces acting to trim the central part of the distribution (i.e., removing common values but preserving the margins), the wheels are set in motion for the creation of separate "types" (i.e., divergence). Such winnowing or trimming can come from a multitude of sources, including cultural preferences for smaller, larger, or novel (in the case of divergence) traits, or from performance characteristics favoring certain design attributes over others. The intersection between transmission and winnowing processes is related to the GT evolutionary notion of "adaptation," where certain variants become more or less popular over time. This is an area where much archaeological research awaits. Note that the rate of evolutionary change in central tendency will be based on the rate at which variation is produced and winnowed and that these factors are all part of the transmission process.

In sum, we argue that scarcity of studies applying CT theory in archaeology is largely a byproduct of the kinds of questions that archaeologists have traditionally asked. Few inquiries in archaeology have been concerned primarily with dispersion and attribute covariation and changes therein over space or time. A refocus on such factors, however, will inform greatly on the rate of technological evolution observed archaeologically and historically (e.g., Basalla 1988). Indeed, we believe that any study hoping to examine change over time in material culture will need to carefully consider the generation and winnowing of variation. In the long run, we predict that CT theory will have an important role to play in such studies.

Persistence, change, and evolution

Another region where CT has much to offer archaeologists is in the analysis of change, or lack thereof, in the archaeological record. Why do some elements of material culture remain in place for thousands of years (or in the case of Acheulean handaxes, hundreds of thousands of years)? Similarly, why do other elements disappear in less than 100 years? Really, these questions concern the study of the evolution of variation and can be rephrased as follows: Why does little variation accrue over long periods of time for some technologies while others change very quickly?

Because it is directly concerned with evolutionary processes, CT theory is particularly informative for providing explanations to answer these questions and, more importantly, for generating predictions for the archaeological record. As discussed above, CT theory suggests that different content (e.g., simple, complex), contexts, and modes of transmission will affect rates of variation production and winnowing. We believe a fruitful line of research in archaeology will be in cross-cultural comparisons of technological change, where different aspects of the factors affecting transmission can be more or less controlled.

Conclusions

As a conceptual framework, CT is especially powerful for explaining patterns observed in material culture and variation therein through time and space. Explanations of artifacts include the aggregate of ideas and processes involved in construction and how these are transmitted between individuals while simultaneously being modified through copying error, individual learning, experimentation, or innovation (e.g., Basalla 1988). Internally, humans confront information through cognitive structures (or filters) that are both learned (e.g., Gabora 2004) and hardwired (e.g., Tooby and Cosmides 1992), as well as biological limitations of the human body itself (e.g., Eerkens 2000; Eerkens and Lipo 2005). These filters act on both the content, context, and mode in which the transmission of information takes place and can transform, winnow, or add to the information transferred. As well, they make for a very complex evolutionary process relative to GT.

As a comprehensive approach to the study of the archaeological record, formal CT models incorporate these processes into their structure and provide a robust foundation for explaining change in material culture over time and space. As such, CT is a flexible theory that can account for a wide range of measurements made in the archaeological record. Moreover, because of its quantitative underpinnings, CT provides archaeologists with falsifiable hypotheses about the structure of material culture. Of course, we will never be able to reconstruct the exact content, context, and mode of acquisition for each transmission event in the past. To apply CT in a useful way, we must look for the larger-scale patterns that result from transmission processes or narrow our search and focus only on those aspects we can control and reconstruct from the archaeological record.

For archaeologists studying material culture from a diachronic perspective, several issues emerged in the review and are summarized below. Many concern or are related to topics archaeologists have historically embraced. In this respect, the application of CT theory in archaeology would not require radical departures from traditional practices or the gathering of new kinds of information using different methods. Indeed, CT theory can be used to reinterpret existing data to provide new views on evolutionary processes of material culture, as many of the examples discussed above have done.

One of the more pertinent issues highlighted is the structuring properties of transmission processes for "neutral" or stylistic variants of material culture. Several archaeological studies followed this approach, producing valuable null models for predicting rates of innovation and allowing archaeologists to propose the presence of pronovelty or proconformity transmission in the past. An interesting future line would be to combine that research with other results gleaned from simulations and/or applications of transmission models to the archaeological record. For example, theory and modeling suggest that the transmission of complex technologies should be characterized by higher population sizes and biased transmission, especially conformist and/or indirect bias. This implies a positive relationship between population size, conformity, complex technologies, and low rates of innovation and change over time. We are unaware of any explorations of the archaeological record that look for such associations, but the predictions from theory have been established in the literature.

A second issue concerns the effects of transmission processes and variation within a population on modal or average behaviors. When dealing with material culture, these effects will be recorded in populations of artifacts, which is why CT is such a useful perspective for archaeologists. Three measures of variation are of particular relevance to CT. The first is the dispersion about a mode or average. Dispersion can be caused by a number of transmission processes such as purposeful experimentation or copying error. The context and content of transmission will have strong effects on this type of variation (e.g., noise in a crowded bar, ritual versus domestic technologies). The second measure of variation concerns the diversity of distinct types within an assemblage of artifacts. Content has less effect on diversity, but as discussed, the context, especially population size and the number of interacting social learners, strongly affects diversity (Henrich 2004b; Lipo 2001a). Also, certain transmission modes are predicted to have strong effects on diversity, such as prestige-biased and conformist transmission, which reduces diversity, and experimentation, which increases it. The third measure of variation involves covariation between the attributes of an artifact or between artifact types themselves. Context is less likely to influence covariation but the content and mode strongly do. Thus, complex technologies are likely to be transmitted in packages where different attributes will be linked. Similarly, prestige-biased and conformist transmission also tends to result in covariation. Worldviews and how people parse out and classify material technologies affect how individuals package cultural information and transmit or acquire it, hence affect covariation. For example, in some worldviews atlatls might be classified as a single entity, while in others the dart point, foreshaft, shaft, and handle might be treated separately as unique entities subject to independent transmission. Few studies have explored the intersection of these three measures of variation (dispersion, diversity, and covariation), particularly as they might be measured in archaeological data sets, though it would seem to be a fruitful area for future research.

A third interesting issue involves the transmission of structure versus detail in material technologies. Little research in archaeology has been undertaken in this regard, however, the results of Washburn (2001) and Mesoudi and Whiten (2004) provide a foundation upon which to build. Washburn was not clear on how to delineate structure from detail in archaeological artifacts outside of art, but her results suggest the record should be patterned differently with respect to these two dimensions. Within groups of people sharing a similar worldview, structure should transmit faithfully (with high fidelity) over time. Detail, however, should accrue significant variation due to copying error, particularly in immigrant communities. Such predictions can be tested using only diachronic empirical data from several contexts, again a potential line of future research for CT studies in archaeology.

Fourth, one of the real values of CT for evolutionary studies is its focus on the behaviors of individuals. Although archaeologists rarely see the actions of individuals, we frequently study artifacts that are the direct byproduct of the behaviors of individuals. If we set up our research questions in the right way, we can use artifacts to inform on these individual behaviors. Other evolutionary approaches in archaeology have typically examined the evolution of higher-level groupings of artifacts, that is, assemblages of artifacts and/or behaviors (e.g., culture history). Unfortunately, we know very little about and have few theoretical models to understand the transmission of such higher-order archaeological units, although CT offers the possibility of modeling or simulating the effects of individuals, which can later be summed to approximate group-level assemblages of artifacts. Again, we believe the analysis of dispersion rather than central tendency will be most informative in such studies.

Finally, we outline what we believe should be some of the central goals of CT research in archaeology in the coming years. First, archaeologists need to complement experimental and simulation studies currently undertaken in other areas of social science. Modern studies are useful for understanding short-term evolutionary processes and/or long-term predictions (for simulation studies) in the transmission of information, but only archaeology can provide the empirical data on actual long-term evolutionary transmission processes. Such a failure would be akin to paleontologists not helping biologists understand long-term genetic evolutionary processes. Second, archaeologists need to do a better job in describing and understanding variation (i.e., dispersion) in artifact assemblages. While important, means and modes (i.e., central tendency) tell only a limited part of the evolutionary story and preclude many kinds of explanation that require an understanding of changes in variability through time and across space. A central goal of CT research should be to develop models and additional theory to help specify measurement requirements and produce explanations of variation. Third, because CT is best understood at the level of the individual person, archaeologists employing CT in their models should do their best to collect data that best approximates this scale. Individual artifact, household, and/or mortuary analyses are most appropriate to this scale, as opposed to analyses of entire midden assemblages or other agglomerative units.

References cited

Aldenderfer, M. A. (1993). Ritual, hierarchy, and change in foraging societies. *Journal of Anthropological Archaeology* **12**: 1–40.

Barkow, J. H. (1975). Prestige and culture: A biosocial interpretation. *Current Anthropology* **16**: 553–576.

Barth, F. (1987). *Cosmologies in the Making: A Generative Approach to Cultural Variation in Inner New Guinea*, Cambridge University Press, New York.

Barth, F. (1990). The guru and the conjurer: Transactions in knowledge and the shaping of culture in Southeast Asia and Melanesia. *Man* **25**: 640–653.

Basalla, G. (1988). *The Evolution of Technology*, Cambridge University Press, Cambridge.

Bentley, R. A. (2005). Academic copying, archaeology and the English language. *Antiquity* **80**: 196–201.

Bentley, R. A., and Maschner, H. D. G. (2000). A growing network of ideas. *Fractals* **8**: 227–238.

Bentley, R. A., and Maschner, H. D. G. (2001). Stylistic change as a self-organized critical phenomenon: An archaeological study in complexity. *Journal of Archaeological Method and Theory* **8**: 35–65.

Bentley, R. A., and Shennan, S. J. (2003). Cultural transmission and stochastic network growth. *American Antiquity* **68**: 459–485.

Bentley, R. A., Hahn, M. W., and Shennan, S. J. (2004). Random drift and culture change. *Proceedings of the Royal Society of London Series B-Biological Sciences* **271**: 1443–1450.

Bettinger, R. L., and Eerkens, J. W. (1997). Evolutionary implications of metrical variation in Great Basin projectile points. In Barton, C. M., and Clark, G. A. (eds.), *Rediscovering Darwin: Evolutionary Theory and Archaeological Explanation*, Archeological Papers No. 7, American Anthropological Association, Arlington, VA, pp. 177–191.

Bettinger, R. L., and Eerkens, J. W. (1999). Point typologies, cultural transmission, and the spread of bow-and-arrow technology in the prehistoric Great Basin. *American Antiquity* **64**: 231–242.

Bettinger, R. L., Boyd, R., and Richerson, P. J. (1996). Style, function, and cultural evolutionary processes. In Maschner, H. D. G. (ed.), *Darwinian Archaeologies*, Plenum Press, New York, pp. 133–164.

Bikhchandani, S., Hirschleifer, D., and Welch, I. (1998). Learning from the behaviour of others: Conformity, fads and informational cascades. *Journal of Economic Perspectives* **12**: 151–170.

Biro, D., Inoue-Nakamura, N., Tonooka, R., Yamakoshi, G., Sousa, C., and Matsuzawa, T. (2003). Cultural innovation and transmission of tool use in wild chimpanzees: Evidence from field experiments. *Animal Cognition* **6**: 213–223.

Blackham, M. (2000). Distinguishing bioturbation and trampling using pottery sherd measures, Tell Fendi, Jordan. *Geoarchaeology* **15**: 469–497.

Boas, F. (1896). The limitations of the comparative method in anthropology. *Science* **4**: 901–907.

Bonner, J. T. (1980). *The Evolution of Culture in Animals*, Princeton University Press, Princeton, NJ.

Boyd, R., and Richerson, P. J. (1985). *Culture and the Evolutionary Process*, University of Chicago Press, Chicago.

Boyd, R., and Richerson, P. J. (1987). The evolution of ethnic markers. *Cultural Anthropology* **2**: 65–79.

Boyd, R., and Richerson, P. J. (1988). An evolutionary model of social learning: The effects of spatial and temporal variation. In Zentall, T., and Galef, B. G. (eds.), *Social Learning: A Psychological and Biological Approach*, Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 29–48.

Boyd, R., and Richerson, P. J. (1995). Why does culture increase human adaptability? *Ethology and Sociobiology* **16**: 125–143.

Boyd, R., and Richerson, P. J. (2002). Group beneficial norms can spread rapidly in a structured population. *Journal of Theoretical Biology* **215**: 287–296.

Brew, J. O. (1946). *Archaeology of Alkali Ridge, Southeastern Utah*, Papers of the Peabody Museum of American Archaeology and Ethnology No. 21, Harvard University, Cambridge, MA.

Brown, C., and Laland, K. N. (2003). Social learning in fishes: A review. *Fish and Fisheries* **4**: 280–288.

Campbell, D. T. (1965). Variation and selective retention in socio-cultural evolution. In Barringer, H. R., Blanksten, G. I., and Mack, R. W. (eds.), *Social Change in Developing Areas: A Reinterpretation of Evolutionary Theory*, Schenkman, Cambridge, MA, pp. 19–49.

Cavalli-Sforza, L. L., and Feldman, M. W. (1973). Models for cultural inheritance. I. Group mean and within group variation. *Theoretical Population Biology* **4**: 42–55.

Cavalli-Sforza, L. L., and Feldman, M. W. (1981). *Cultural Transmission and Evolution: A Quantitative Approach*, Princeton University Press, Princeton, NJ.

Cavalli-Sforza, L. L., and Feldman, M. W. (1983). Paradox of the evolution of communication and of social interactivity. *Proceedings of the National Academy of Sciences* **80**: 2017–2021.

Cloak, F. T., Jr. (1975). Is a cultural ethology possible? *Human Ecology* **3**: 161–182.

Combet, F., Jaussaud, P., and Martin, N. (2005). Estimation of slight speed gaps between signals via the scale transform. *Mechanical Systems & Signal Processing* **19**: 230–257.

Conkey, M., and Hastorf, C. (eds.) (1990). *The Use of Style in Archaeology*, University of Cambridge Press, Cambridge.

Coren, S. L., Ward, L. M., and Enns, J. T. (1994). *Sensation and Perception*, Harcourt Brace, Fort Worth, TX.

Cover, T. M., and Thomas, J. A. (1991). *Elements of Information Theory*, Wiley, New York.

Cronk, L. (1999). *That Complex Whole: Culture and the Evolution of Human Behavior*, Westview, Boulder, CO.

Dawkins, R. (1976). *The Selfish Gene*, Oxford University Press, New York.

Dawkins, R. (1982). *The Extended Phenotype*, Oxford University Press, Oxford.

De Winter, W. (1997). The beanbag genetics controversy: Towards a synthesis of opposing views of natural selection. *Biology and Philosophy* **12**: 149–184.

Deetz, J. (1965). *The Dynamics of Stylistic Change in Arikara Ceramics*, Illinois Studies in Anthropology, Urbana.

Deetz, J., and Dethlefsen, E. S. (1965). The Doppler-effect and archaeology: A consideration of the spatial aspects of seriation. *Southwestern Journal of Anthropology* **21**: 196–206.

Deetz, J., and Dethlefsen, E. S. (1971). Some social aspects of New England colonial mortuary art. In Brown, J. A. (ed.), *Memoirs of the Society for American Archaeology*, No. 25, Society for American Archaeology, Washington, DC, pp. 30–38.

Dobres, M. A. (2000). Creativity in human evolution and prehistory. *American Antiquity* **65**: 768–769.

Doolittle, W. F., and Sapienza, C. (1980). Selfish genes, the phenotype paradigm and genome evolution. *Nature* **284**: 601–603.

Dunnell, R. C. (1971). *Systematics in Prehistory*, Free Press, New York.

Dunnell, R. C. (1978). Style and function: A fundamental dichotomy. *American Antiquity* **43**: 192–202.

Dunnell, R. C. (1985). Methodological issues in contemporary Americanist archaeology. In Asquith, P. D., and Ketcher, P. (eds.), *Proceedings of the 1984 Biennial Meetings of the Philosophy of Science Association, Volume 2*, Philosophy of Science Association, East Lansing, MI, pp. 717–744.

Dunnell, R. C. (1992). Archaeology and evolutionary science. In Wandsnider, L. (ed.), *Quandaries and Quests: Visions of Archaeology's Future*, Occasional Paper No. 20, Center for Archaeological Investigations, Southern Illinois University Press, Carbondale, pp. 209–221.

Durham, W. H. (1976). The adaptive significance of cultural behavior. *Human Ecology* **4**: 89–121.

Eerkens, J. W. (2000). Practice makes within 5% of perfect: The role of visual perception, motor skills, and human memory in artifact variation and standardization. *Current Anthropology* **41**: 663–668.

Eerkens, J. W., and Bettinger, R. L. (2001). Techniques for assessing standardization in artifact assemblages: Can we scale material variability? *American Antiquity* **66**: 493–504.

Eerkens, J. W., and Lipo, C. P. (2005). Cultural transmission, copying errors, and the generation of variation in material culture in the archaeological record. *Journal of Anthropological Archaeology* **24**: 316–334.

Feathers, J. K. (1989). Ceramic analysis, variation, and database construction: A selectionist perspective. In Blakely, J. A., and Bennett, W. J. J. (eds.), *Analysis and Publication of Ceramics: The Computer Database in Archaeology*, BAR International Series 551, British Archaeological Reports, Oxford, pp. 71–80.

Feathers, J. K. (1990). *Explaining the Evolution of Ceramics in Southeast Missouri*, Unpublished Ph.D. dissertation, Department of Anthropology, University of Washington, Seattle.

Feldman, M. W., Aoki, K., and Kumm, J. (1996). Individual versus social learning: Evolutionary analysis in a fluctuating environment. *Anthropological Science* **104**: 209–232.

Ford, J. A. (1935). *Ceramic Decoration Sequence at an Old Indian Village Site, Near Sicily Island, Louisiana,* Anthropological Study No. 1, Department of Conservation, Louisiana Geological Survey, New Orleans.

Ford, J. A. (1936). *Analysis of Indian Village Site Collections from Louisiana and Mississippi*, Anthropological Study No. 2, Department of Conservation, Louisiana Geological Survey, New Orleans.

Ford, J. K. B. (1991). Vocal traditions among resident killer whales (*Orcinus orca*) in coastal waters of British Columbia. *Canadian Journal of Zoology* **69**: 1454–1483.

Fritz, J., and Kotraschal, K. (1999). Social learning in common ravens (*Corvus corax*). *Animal Behavior* **57**: 785–793.

Fromkin, V., and Rodman, R. (1997). *An Introduction to Language*, 6th ed., Harcourt Brace, London.

Gabora, L. M. (2000). The beer can theory of creativity. In Bentley, P., and Corne, D. (eds.), *Creative Evolutionary Systems*, Morgan Kaufman, San Francisco, pp. 1–26.

Gabora, L. M. (2004). Ideas are not replicators but minds are. *Biology and Philosophy* **19**: 127–143.

Gell-Mann, M., and Lloyd, S. (2003). *Effective Complexity*, Santa Fe Institute Working Paper 03-12-068, Santa Fe, NM.

Gibbs, W. W. (2003). The unseen genome: Gems among the junk. *Scientific American* **289**: 46–53.

Grant, P., and Grant, R. (1996). Cultural inheritance of song and its role in the evolution of Darwin's finches. *Evolution* **50**: 2471–2487.

Hahn, M. W., and Bentley, R. A. (2003). Drift as a mechanism for cultural change: An example from baby names. *Proceedings of the Royal Society Biology Letters* **B270**: S120–S123.

Harpole, J., and Lyman, R. L. (2002). Changes in the fashion of women's bonnets, 1831–1895. *Missouri Archaeologist* **63**: 21–30.

Hatch, E. (1973). *Theories of Man and Culture*, Columbia University Press, New York.

Hayden, B. (ed.) (1979). *Lithic Use-Wear Analysis*, Academic Press, New York.

Henrich, J. (2001). Cultural transmission and the diffusion of innovations: Adoption dynamics indicate that biased cultural transmission is the predominant force in behavioral change. *American Anthropologist* **103**: 992–1013.

Henrich, J. (2004a). Cultural group selection, coevolutionary processes and large-scale cooperation. *Journal of Economic Behavior and Organization* **53**: 3–35.

Henrich, J. (2004b). Demography and cultural evolution: Why adaptive cultural processes produced maladaptive losses in Tasmania. *American Antiquity* **69**: 197–221.

Henrich, J., and Boyd, R. (1998). The evolution of conformist transmission and between-group differences. *Evolution and Human Behavior* **19**: 215–242.

Henrich, J., and Boyd, R. (2001). Why people punish defectors: Conformist transmission stabilizes costly enforcement of norms in cooperative dilemmas. *Journal of Theoretical Biology* **208**: 79–89.
Henrich, J., and Boyd, R. (2002). Culture and cognition: Why cultural evolution does not require replication of representations. *Culture and Cognition* **2**: 87–112.
Henrich, J., and Gil-White, F. J. (2001). The evolution of prestige: Freely conferred deference as a mechanism for enhancing the benefits of cultural transmission. *Evolution and Human Behavior* **22**: 165–196.
Henrich, J., and McElreath, R. (2003). The evolution of cultural evolution. *Evolutionary Archaeology* **12**: 123–135.
Herzog, H. A., Bentley, R. A., and Hahn, M. W. (2004). Random drift and large shifts in popularity of dog breeds. *Proceedings of the Royal Society of London Series B-Biological Sciences* **271**: S353–S356.
Heyes, C. M., and Galef, J. B. G. (eds.) (1996). *Social Learning in Animals: The Roots of Culture*, Academic Press, London.
Hill, J. N. (1966). A prehistoric community in eastern Arizona. *Southwestern Journal of Anthropology* **22**: 9–30.
Hill, J. N. (1968). Broken K Pueblo: Patterns of form and function. In Binford, S. R., and Binford, L. R. (eds.), *New Perspectives in Archeology*, Aldine, Chicago, pp. 103–142.
Holmes, W. H. (1886). Ancient Pottery of the Mississippi Valley, Fourth Annual Report of the Bureau of Ethnology, 1882–83, Smithsonian Institution, Washington, DC, pp. 361–436.
Houston, S., Stuart, D., and Robertson, J. (1998). Disharmony in Maya hieroglyphic writing: Linguistic change and continuity in Classic society. In Ciudad Ruiz, A., Fernandez Marquinez, Y., Garcia Campillo, J. M., Iglesias Ponce de Leon, M. J., Garcia-Gallo, A. L., and Sanz Castro, L. T. (eds.), *Anatomía de una civilización: aproximaciones interdisciplinarias a la cultura maya*, Sociedad Española de Estudios Mayas, Madrid, pp. 275–296.
Hruby, Z. X. (2002). Evidence for linguistic conservatism in the hieroglyphic script of the central Peten. *Mayab* **15**: 49–59.
Jordan, P., and Shennan, S. (2003). Cultural transmission, language, and basketry traditions amongst the California Indians. *Journal of Anthropological Archaeology* **22**: 42–74.
Kidder, A. V. (1915). Pottery of the Pajarito Plateau and some adjacent regions in New Mexico. In *Memoirs of the American Anthropological Association*, Vol. 2, American Anthropological Association, Lancaster, pp. 407–462.
Kidder, A. V. (1917). A design-sequence from New Mexico. *Proceedings of the National Academy of Sciences* **3**: 369–370.
Kohler, T. A., VanBuskirk, S., and Ruscavage-Barz, S. (2004). Vessels and villages: Evidence for conformist transmission in early village aggregations on the Pajarito Plateau, New Mexico. *Journal of Anthropological Archaeology* **23**: 100–118.
Koppers, W. (1955). Diffusion: Transmission and acceptance. *Yearbook of Anthropology* **1955**: 169–181.
Kornbacher, K. (2001). Building components of evolutionary explanation: A study of wedge tools from northern South America. In Hunt, T., Lipo, C. P., and Sterling, S. (eds.), *Posing Questions for a Scientific Archaeology*, Bergin and Garvey, Westport, CT, pp. 23–72.
Krieger, A. D. (1944). The typological concept. *American Antiquity* **3**: 271–288.
Kroeber, A. L. (1916). *Zuni Potsherds*, Anthropological Paper No. 18, Part 1, American Museum of Natural History, New York.
Kroeber, A. L. (1919). On the principle of order in civilization as exemplified by changes of fashion. *American Anthropologist* **21**: 235–263.
Kroeber, A. L. (1940). Statistical classification. *American Antiquity* **6**: 29–44.
Krützen, M., Mann, J., Heithaus, M. R., Connor, R. C., Bejder, L., and Sherwin, W. B. (2005). Cultural transmission of tool use in bottlenose dolphins. *Proceedings of the National Academy of Sciences* **102**: 8939–8943.
Kuijt, I. (2000). People and space in early agricultural villages: Exploring daily lives, community size and architecture in the late pre-pottery Neolithic. *Journal of Anthropological Archaeology* **19**: 75–102.
Kujit, I. (2001). Place, death, and the transmission of social memory in early agricultural communities of the Near Eastern Pre-Pottery Neolithic. In Chesso, M. S. (ed.), *Social Memory, Identity, and Death: Intradisciplinary Perspectives on Mortuary Rituals*, American Anthropological Association, Washington, DC, pp. 80–99.
Labov, W. (1972). The social motivation of a sound change. In Labov, W. (ed.), *Sociolinguistic Patterns*, University of Pennsylvania Press, Philadelphia, pp. 1–42.
Labov, W. (1994). *Principles of Linguistic Change: Internal Factors*, Basil Blackwell, Oxford.

Lewontin, R. (1974). *The Genetic Basis of Evolutionary Change*, Columbia University Press, New York.
Lieberson, S. (2000). *A Matter of Taste: How Names, Fashions, and Culture Change*, Yale University Press, New Haven, CT.
Lipo, C. (2001a). *Science, Style and the Study of Community Structure: An Example from the Central Mississippi River Valley*, BAR International Series, No. 918, British Archaeological Reports, Oxford.
Lipo, C. (2001b). Community structures among late Mississippian populations of the central Mississippi River valley. In Hunt, T., Lipo, C. P., and Sterling, S. (eds.), *Posing Questions for a Scientific Archaeology*, Bergin and Garvey, Westport, CT, pp. 175–216
Lipo, C., and Madsen, M. (2000). Neutrality, "style," and drift: Building methods for studying cultural transmission in the archaeological record. In Hurt, T. D., and Rakita, G. F. M. (eds.), *Style and Function: Conceptual Issues in Evolutionary Archaeology*, Bergin and Garvey, Westport, CT, pp. 91–118.
Lipo, C., Madsen, M., Dunnell, R., and Hunt, T. (1997). Population structure, cultural transmission, and frequency seriation. *Journal of Anthropological Archaeology* **16**: 301–333.
Longacre, W. A. (1970). *Archaeology as Anthropology: A Case Study*, University of Arizona Press, Tucson.
Lumsden, C. J., and Wilson, E. O. (1981). *Genes, Mind and Culture*, Harvard University Press, Cambridge, MA.
Lyman, R. L. (2000). Culture historical and biological approaches to identifying homologous traits. In Hurt, T. D., and Rakita, G. F. M. (eds.), *Style and Function. Conceptual Issues in Evolutionary Archaeology*, Bergin and Garvey, Westport, CT, pp. 69–89.
Lyman, R., and O'Brien, M. (2000). Measuring and explaining change in artifact variation with clade-diversity diagrams. *Journal of Anthropological Archaeology* **19**: 39–74.
Lyman, R. L., and O'Brien, M. J. (2003). Cultural traits: Units of analysis in early twentieth-century anthropology. *Journal of Anthropological Research* **59**: 225–250.
Lyman, R. L., O'Brien, M. J., and Dunnell, R. C. (1997). *The Rise and Fall of Culture History*, Plenum Press, New York.
Lynch, A. (1996). The population memetics of birdsong. In Kroodsma, D. E., and Miller, E. H. (eds.), *Ecology and Evolution of Acoustic Communication in Birds*, Cornell University Press, Ithaca, NY, pp. 181–197.
MacDonald, D. (1998). Subsistence, sex, and cultural transmission in Folsom culture. *Journal of Anthropological Archaeology* **17**: 217–239.
Mayr, E. (1959). Where are we. *Cold Spring Harbor Symposium in Quantitative Biology* **24**: 1–14.
McBrearty, S., Bishop, L., Plummer, T., Dewar, R., and Conard, N. (1998). Tools underfoot: Human trampling as an agent of lithic artifact edge modification. *American Antiquity* **63**: 108–129.
McClure, S. B. (2004). *Cultural Transmission of Ceramic Technology During the Consolidation of Agriculture in Valencia, Spain*, Ph.D. dissertation, Department of Anthropology, University of California, Santa Barbara, University Microfilms, Ann Arbor.
McElreath, R., Boyd, R., and Richerson, P. J. (2003). Shared norms and the evolution of ethnic markers. *Current Anthropology* **44**: 122–129.
McGrew, W. (1992). *Chimpanzee Material Culture. Implications for Human Evolution*, Cambridge University Press, Cambridge.
Meggers, B., Evans, C., and Estrada, B. (1965). *Early Formative Period of Coastal Ecuador: The Valdivia and Machalilla Phases*, Smithsonian Contributions to Anthropology I, Smithsonian Institution, Washington, DC.
Meltzer, D. J. (1981). A study of style and function in a class of tools. *Journal of Field Archaeology* **8**: 313–326.
Mesoudi, A., and Whiten, A. (2004). The hierarchical transformation of event knowledge in human cultural transmission. *Journal of Cognition and Culture* **4**: 1–24.
Mesoudi, A., Whiten, A., and Dunbar, R. I. M. (2006). A bias for social information in human cultural transmission. *British Journal of Psychology* **97**: 405–423.
Mithen, S. J. (1997). Cognitive archaeology, evolutionary psychology, and cultural transmission with particular reference to religious ideas. In Barton, C. M., and Clark, G. A. (eds.), *Rediscovering Darwin: Evolutionary Theory in Archaeological Explanation*, Archeological Paper No. 7, American Anthropological Association, Washington, DC, pp. 67–74.

Mithen, S. J. (1998). A creative explosion? Theory of mind, language, and the disembodied mind of the Upper Paleolithic. In Mithen, S. J. (ed.), *Creativity in Human Evolution and Prehistory*, Routledge, London, pp. 165–191.

Neiman, F. (1995). Stylistic variation in evolutionary perspective: Inferences from decorative diversity and interassemblage distance in Illinois Woodland ceramic assemblages. *American Antiquity* **60**: 7–36.

Nelson, N. C. (1916). Chronology of the Tanos ruins, New Mexico. *American Anthropologist* **18**: 159–180.

Nishida, T. (1968). The social group of wild chimpanzees in the Mahali Mountains. *Primates* **9**: 167–224.

Norwich, K. H. (1983). On the theory of Weber fractions. *Perception and Psychophysics* **42**: 286–298.

O'Brien, M. J., and Holland, T. D. (1990). Variation, selection, and the archaeological record. In Schiffer, M. B. (ed.), *Archaeological Method and Theory*, Vol. 2, University of Arizona Press, Tucson, pp. 31–80.

O'Brien, M. J., and Lyman, R. L. (1999). *Seriation, Stratigraphy, and Index Fossils: The Backbone of Archaeological Dating*, Kluwer Academic/Plenum Press, New York.

O'Brien, M. J., and Lyman, R. L. (2002). The epistemological nature of archaeological units. *Anthropological Theory* **2**: 37–56.

O'Brien, M. J., and Lyman, R. L. (2003). Style, function, transmission: An introduction. In O'Brien, M. J., and Lyman, R. L. (eds.), *Style, Function, Transmission: Evolutionary Archaeological Perspectives*, University of Utah Press, Salt Lake City, pp. 1–32.

O'Brien, M. J., Holland, T. D., Hoard, R. J., and Fox, G. L. (1994). Evolutionary implications of design and performance characteristics of prehistoric pottery. *Journal of Archaeological Method and Theory* **1**: 259–304.

O'Brien, M. J., Lyman, R. L., and Schiffer, M. B. (2005). *Archaeology as a Process: Processualism and Its Progeny*, University of Utah Press, Salt Lake City.

Olsen, S. L., and Shipman, P. (1988). Surface modification on bone: Trampling versus butchery. *Journal of Archaeological Science* **15**: 535–553.

Orgel, L. E., and Crick, F. H. C. (1980). Selfish DNA: The ultimate parasite. *Nature* **284**: 604–607.

Osgood, C. (1951). Culture: Its empirical and non-empirical character. *Southwestern Journal of Anthropology* **7**: 202–214.

Palmer, C. T., and Wright, S. A. (1997). Categories and gatherings: Group selection and the mythology of cultural anthropology. *Evolution and Human Behavior* **18**: 291–308.

Palmer, C. T., Coe, K., and Wadley, R. L. (2005). On tools and tradition. *Current Anthropology* **46**: 459–460.

Palmer, C. T., Frederickson, B. E., and Tilley, C. F. (1995). On cultural group selection. *Current Anthropology* **36**: 657–658.

Petrie, W. M. F. (1899). Sequences in prehistoric remains. *Journal of the Royal Anthropological Institute of Great Britain and Ireland* **29**: 295–301.

Pfeffer, M. T. (2001). The engineering and evolution of Hawaiian fishhooks. In Hunt, T. L., Lipo, C. P., and Sterling, S. (eds.), *Posing Questions for a Scientific Archaeology*, Bergin and Garvey, Westport, CT, pp. 73–96.

Phillips, P., Ford, J. A., and Griffin, J. B. (1951). *Archaeological Survey in the Lower Mississippi Alluvial Valley, 1940–1947*, Papers of the Peabody Museum of American Archaeology and Ethnology 25, Harvard University, Cambridge, MA.

Pocklington, R., and Best, M. L. (1997). Cultural evolution and units of selection in replicating text. *Journal of Theoretical Biology* **188**: 79–87.

Poole, J. H., Tyack, P. L., Stoeger-Horwath, A. S., and Watwood, S. (2005). Animal behaviour: Elephants are capable of vocal learning. *Nature* **434**: 455–456.

Popper, K. (1959). *The Logic of Scientific Discovery*, Basic Books, New York.

Rendell, L., and Whitehead, H. (2001). Culture in whales and dolphins. *Behavioral and Brain Sciences* **24**: 309–382.

Rickerson, P. J., and Boyd, R. (1978). A dual inheritance model of the human evolutionary process. *Journal of Social and Biological Structures* **1**: 127–154.

Rogers, E. M. (2003). *The Diffusion of Innovations*, 5th ed., Free Press, New York.

Rouse, I. (1939). *Prehistory in Haiti*, Yale University Publications in Anthropology No. 21, New Haven, CT.

Rowlands, M. (1993). The role of memory in the transmission of culture. *World Archaeology* **25**: 141–151.

Schiffer, M. B. (1987). *Formation Processes of the Archaeological Record*, University of New Mexico Press, Albuquerque.

Schiffer, M. B. (2004). Memes are a bad idea: Behavioral approaches to cultural transmission and evolution. Paper presented at the 68th Annual Meeting for the Society for American Archaeology, Montreal.

Schiffer, M. B., and Skibo, J. M. (1997). The explanation of artifact variability. *American Antiquity* **62**: 27–50.

Schiffer, M. B., Skibo, J. M., Griffitts, J. L., Hollenback, K. L., and Longacre, W. A. (2001). Behavioral archaeology and the study of technology. *American Antiquity* **66**: 729–737.

Schlag, K. H. (1998). Why imitate, and if so, how? *Journal of Economic Theory* **78**: 130–156.

Shannon, C. E., and Weaver, W. (1949). *The Mathematical Theory of Communication*, University of Illinois Press, Urbana.

Sheng-Wei, L., Jin-Jang, L., and Li-Wei, K. (2004). An error resilient coding scheme for H.26L video transmission based on data embedding. *Journal of Visual Communication and Image Representation* **15**: 214–240.

Shennan, S. J. (1989). Cultural transmission and cultural change. In Van der Leeuw, S. E., and Torrance, R. (eds.), *What's New: A Closer Look at the Process of Innovation*, Unwin Hyman, London, pp. 330–346.

Shennan, S. J. (2001). Demography and cultural innovation: A model and its implications for the emergence of modern human culture. *Cambridge Archaeological Journal* **11**: 5–16.

Shennan, S. J. (2002). *Genes, Memes, and Human History: Darwinian Archaeology and Cultural Evolution*, Thames and Hudson, London.

Shennan, S. J., and Wilkinson, J. R. (2001). Ceramic style change and neutral evolution: A case study from Neolithic Europe. *American Antiquity* **66**: 577–593.

Shott, M. J. (1997). Stones and shafts redux: The metric discrimination of chipped-stone dart and arrow points. *American Antiquity* **62**: 86–101.

Skibo, J. M. (1992). *Pottery Function: A Use-Alteration Perspective*, Plenum Press, New York.

Slater, P. J. B., and Ince, S. A. (1979). Cultural evolution in chaffinch song. *Behavior* **71**: 146–166.

Smith, J. M., and Bell, P. A. (1994). Conformity as a determinant of behavior in a resource dilemma. *Journal of Social Psychology* **134**: 191–200.

Soltis, J., Boyd, R., and Richerson, P. J. (1995). Can group-functional behaviors evolve by cultural group selection? An empirical test. *Current Anthropology* **36**: 473–494.

Spencer, C. (1993). Human agency, biased transmission, and the cultural evolution of chiefly authority. *Journal of Anthropological Archaeology* **12**: 41–74.

Sperber, D. (1996). *Explaining Culture: A Naturalistic Approach*, Blackwell, Oxford.

Spier, L. (1917). *An Outline for a Chronology of Zuni Ruins*, Anthropological Papers No. 18, Part 3, American Museum of Natural History, New York.

Tehrani, J., and Collard, M. (2002). Investigating cultural evolution through biological phylogenetic analyses of Turkmen textiles. *Journal of Anthropological Archaeology* **21**: 443–463.

Teltser, P. A. (1995). Culture history, evolutionary theory, and frequency seriation. In Teltser, P. A. (ed.), *Evolutionary Archaeology: Methodological Issues*, University of Arizona Press, Tucson, pp. 51–68

Tooby, J., and Cosmides, L. (1992). Psychological foundations of culture. In Barkow, J. H., Cosmides, L., and Tooby, J. (eds.), *The Adapted Mind*, Oxford University Press, New York, pp. 19–136.

Trask, R. L. (1994). *Language Change*, Routledge, New York.

van Doorn, A. J., van de Grind, W. A., and Koenderink, J. J. (1984). *Limits in Perception: Essays in Honour of Maarten A. Bouman*, VNU Science Press, Utrecht, The Netherlands.

Wang, R., Hong, F., and Chen, Z. (2004). Cryptography with no transmission error or cipher-text extension based on orthogonal table. *Mini-Micro Systems* **25**: 1499–1501.

Washburn, D. K. (2001). Remembering things seen: Experimental approaches to the process of information transmittal. *Journal of Archaeological Method and Theory* **8**: 67–99.

Whitehouse, H. (1992). Memorable religions: Transmission, codification and change in divergent Melanesian contexts. *Man* **27**: 777–799.

Wilhelmsen, K. H. (2001). Building the framework for an evolutionary explanation of projectile point variation: An example from the central Mississippi River valley. In Hunt, T. L., Lipo, C. P., and Sterling, S. (eds.), *Posing Questions for a Scientific Archaeology*, Bergin and Garvey, Westport, CT, pp. 97–144.

Woese, C. R. (2000). Interpreting the universal phylogenetic tree. *Proceedings of the National Academy of Sciences* **97**: 8392–8396.

Woese, C. R. (2004). A new biology for a new century. *Microbiology and Molecular Biology Reviews* **68**: 173–186.

Wrangham, R., McGrew, W., de Waal, F., and Heltne, P. (1996). *Chimpanzee Cultures*, Harvard University Press, Cambridge, MA.

Bibliography of recent literature

Atran, S. (2001). The trouble with memes: Inference versus imitation in cultural creation. *Human Nature* **12**: 351–381.

Aunger, R. (2002). *The Electric Meme: A New Theory of How We Think*, Free Press, New York.

Barton, C. M., and Clark, G. A. (1997). Evolutionary theory and archaeological explanation. In Barton, C. M., and Clark, G. A. (eds.), *Rediscovering Darwin: Evolutionary Theory and Archaeological Explanation*, Archeological Papers Vol. 7, American Anthropological Association, Arlington, VA, pp. 3–15.

Beck, C. (1998). Projectile point types as valid chronological units. In Ramenofsky, A. F., and Steffen, A. (eds.), *Unit Issues in Archaeology: Measuring Time, Space, and Material*, University of Utah Press, Salt Lake City, pp. 21–40.

Bentley, R. A. (2003). Cultural transmission and stochastic network growth. *American Antiquity* **68**: 459–485.

Best, M. L., and Pocklington, R. (1999). Meaning as use: Transmission fidelity and evolution in netnews. *Journal of Theoretical Biology* **196**: 389–395.

Boone, J. L., and Smith, E. A. (1998). Is it evolution yet? A critique of evolutionary archaeology. *Current Anthropology* **39**: 141–173.

Boyd, R., and Richerson, P. J. (1987). The evolution of ethnic markers. *Cultural Anthropology* **2**: 65–79.

Boyd, R., and Richerson, P. J. (1996). Why culture is common but cultural evolution is rare. *Proceedings of the British Academy* **88**: 77–93.

Boyd, R., and Richerson, P. J. (2002). Group beneficial norms spread rapidly in a structured population. *Journal of Theoretical Biology* **215**: 287–296.

Boyer, P. (1999). Cognitive tracks of cultural inheritance: How evolved intuitive ontology governs cultural transmission. *American Anthropologist* **100**: 876–889.

Broughton, J. M., and O'Connell, J. F. (1999). On evolutionary ecology, selectionist archaeology, and behavioral archaeology. *American Antiquity* **64**: 153–165.

Darwent, J., and O'Brien, M. J., (2005). Using cladistics to construct lineages of projectile points from northeastern Missouri. In Lipo, C. L., O'Brien, M. J., Collard, M., and Shennan, S. J. (eds.), *Mapping Our Ancestors: Phylogenetic Approaches in Anthropology and Prehistory*, Aldine, New York, pp. 185–208.

Henrich, J. (2001). Cultural transmission and the diffusion of innovations: Adoption dynamics indicate that biased cultural transmission is the predominate force in behavioral change. *American Anthropologist* **103**: 992–1013.

Henrich, J., and Boyd, R. (2002). Culture and cognition: Why cultural evolution does not require replication of representations. *Culture and Cognition* **2**: 87–112.

Jones, G. T, Leonard, R. D., and Abbot, A. L. (1995). The structure of selectionist explanations in archaeology. In Teltser, P. A. (ed.), *Evolutionary Archaeology: Methodological Issues*, University of Arizona Press, Tucson, pp. 13–32.

Lanata, J. L., and Neff, H. (1999). Discutiendo algunas escalas of transmision cultural: artefacto y espacio. *Revista do Museo de Arquelogia y Etnologia (Sao Paulo), Supplemento* **3**: 46–56.

Lipo, C. L., O'Brien, M. J., Collard, M., and Shennan, S. J. (eds.) (2005). *Mapping Our Ancestors: Phylogenetic Approaches in Anthropology and Prehistory*, Aldine, New York.

Lynch, A. (1996). *Thought Contagion: How Belief Spreads Through Society*, Basic Books, New York.

Mesoudi, A., Whiten, A., and Laland, K. N. (2004). Perspective: Is human cultural evolution Darwinian? Evidence reviewed from the perspective of the *Origin of Species*. *Evolutionary Anthropology* **58**: 1–11.

Neff, H. (2000). On evolutionary ecology and evolutionary archaeology: Some common ground? *Current Anthropology* **41**: 427–429.

O'Brien, M. J., and Lyman, R. L. (2000). Measuring and explaining change in artifact variation with clade-diversity diagrams. *Journal of Anthropological Archaeology* **19**: 39–74.

O'Brien, M. J., and Lyman, R. L. (2004). History and explanation in archaeology. *Anthropological Theory* **4**: 173–197.
O'Brien, M. J., Darwent, J., and Lyman, R. L. (2001). Cladistics is useful for reconstructing archaeological phylogenies: Paleoindian points from the southeastern United States. *Journal of Archaeological Science* **28**: 1115–1136.
Pierce, C. (1998). Theory, measurement, and explanation, variable shapes in poverty point objects. In Ramenofsky, A. F., and Steffen, A. (eds.), *Unit Issues in Archaeology: Measuring Time, Space, and Material*, University of Utah Press, Salt Lake City, pp. 163–190.
Richerson, P. J., Boyd, R., and Henrich, J. (2003). The cultural evolution of human cooperation. In Hammerstein, P. (ed.), *The Genetic and Cultural Evolution of Cooperation*, MIT Press, Cambridge, MA, pp. 357–388.
Shennan, S. J. (2002). Learning. In Hart, J. P., and Terrell, J. E. (eds.), *Darwin and Archaeology: A Handbook of Key Concepts*, Bergin and Garvey, Westport, CT, pp. 183–200.
Taylor, G. (1996). *Cultural Selection*, BasicBooks, New York.
Tschauner, H. (1994). Archaeological systematics and cultural evolution: Retrieving the honour of culture history. *Man* **29**: 77–93.