Chapter 14
The Future of Paleolithic Studies: A View from the New World

Michael J. O'Brien

Abstract Paleolithic studies have a long tradition in European and American archaeology, beginning in serious fashion with the work of John Lubbock in Britain and later with that of William Henry Holmes in the United States. Research questions that have been asked with respect to the Paleolithic period have changed dramatically over the decades, but the interest in stone tools as major sources of information on prehistoric peoples has not. In the New World, the last decade has witnessed a shift in research emphasis back to questions of culture history, but the methods and techniques now being brought to bear on the questions are entirely modern in how they address issues of cultural relatedness. Without an ability to distinguish between cases of technological convergence and cases of homologous similarity, we can never hope to untangle prehistory. The methods and techniques now being used are geared specifically for that purpose. Most important, they yield testable results as opposed to impressions. As a result, we now have unparalleled views into Paleolithic life in the New World.

Introduction

I appreciate the invitation to contribute a chapter to this volume. I state at the outset that I am not a Paleolithic specialist, usually finding myself on the sidelines when the subject turns to the finer points of stone-tool manufacture or how to recognize various traces of use-wear. I have, however, developed some degree of competency with respect to ways in which stone tools can be used to answer interesting archaeological questions, and it is solely from that perspective that I write this essay. I subtitle the piece "*A* View" because that's what it is – not a long-range perspective of where Paleolithic studies might be 20 years from now but rather a narrow view of what I see as some interesting research questions and the promising avenues that are being followed to answer them.

M.J. O'Brien (✉)
Department of Anthropology, University of Missouri,
317 Lowry Hall, Columbia, MO, 65211-6080, USA
e-mail: ObrienM@missouri.edu

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I have no adequate means of calculating the number of publications focusing primarily or exclusively on the Paleolithic that appear annually, but it is substantial. The sheer number of studies ensures that competing views are always in the mix – a pluralism that presents an extraordinarily diverse smorgasbord from which future studies can sample. Certainly, the chapters included here attest to that pluralism. I limit my discussion, however, to what might broadly be defined as culture history, but I come at it from the standpoint of evolution. In that respect, I echo Kuhn's (2004:561) remark that "evolutionary concepts and models provide some of the best tools for learning about the kinds of long-term processes that engage my interest."

I sometimes wonder what prehistorians working a 100 years ago would think of the myriad directions in which archaeology has headed. For example, what would William Henry Holmes think of modern Paleolithic studies? Certainly Holmes, from his vantage point in the Bureau of American Ethnology, witnessed the prominent role that stone artifacts played in understanding the Paleolithic of both Europe and North America, especially with respect to the antiquity of human occupation of the latter. More important here was the role that Holmes played. In several clear, not to mention clever, expositions of the problems one can face in putting all one's eggs in an analogical basket, Holmes brilliantly succeeded in demonstrating that supposed widespread evidence of glacial-age humans in North America was, in fact, no evidence at all.

As received wisdom had it (e.g., Abbott 1881), if certain chipped-stone artifacts from North America were identical in form to those recovered from undisputed early (glacial-age) European Paleolithic contexts, then North America had experienced its own early Paleolithic stage. One characteristic of many of the chipped-stone pieces recovered from North American contexts was their crude appearance – cruder certainly than the well-made projectile points and other shaped tools familiar to North American prehistorians. Given the then-current views on cultural evolution and the ladderlike nature of unilinear evolutionary schemes made popular by Lubbock (1865) and others, it was difficult *not* to make the assumption that technologically "inferior" tools (or, more precisely, what were assumed to be tools) were left by earlier people – a position that appeared to be strengthened by reports of similar inferior pieces being found in glacial-age gravel deposits across the midwestern and eastern United States. Prehistorians reasoned that if the gravel beds dated to the glacial period, and the beds contained tools, then the obvious conclusion was that humans had inhabited North America during the so-called "ice age."

The faulty logic behind this argument was not lost on Holmes, who began as early as 1890 with a series of articles aimed at discrediting the great antiquity of humans in the New World (e.g., Holmes 1893). These led to his excavations in Piney Branch and related stone quarries in and around Washington, D.C., and finally to his article "Stone Implements of the Potomac – Chesapeake Tidewater Province" (Holmes 1897). In it, Holmes conclusively demonstrated that what were considered to be early "tools" were nothing more than quarry blanks and rejects. Several decades later, a small projectile point from northeastern New Mexico (Figgins 1927) would demonstrate that indeed humans *had* been in North America much earlier than Holmes expected, but that's not important here. What *is* important is the take-home message that came from Holmes's work: Don't confuse analogous similarity with homologous similarity. Homology implies *relatedness* through some transmission process, whereas analogy implies convergence on a common solution to a problem without transmission. The issue would appear to be particularly consequential with respect to Paleolithic studies, where, on the one hand, "patterns in technology have been used to reconstruct population histories… . [while] on the other hand stone tools can be and have been interpreted as adaptive markers, often with little or no phylogenetic signal, because they are endlessly thrown up convergently by the demands of the environment and social organization, which thus reflect variability in behavioral response" (Foley and Lahr 2003:110). In other words, there are only so many ways to make stone tools, and unrelated toolmakers must have found common solutions to environmental "problems" countless times the world over. How does one know when two things are similar because they are related as opposed to possibly being related because they are similar?

I examine the issue of analogous versus homologous similarity in more detail below, using that discussion as a lead-in to a broad issue that underlies many of the chapters here, cultural transmission. In my opinion, there is no "hotter" topic in archaeology and one that transcends where in the world one works or where one was trained. In one respect, it is rather ironic to state that cultural transmission is currently a hot topic, given the centrality of transmission, in one guise or another, in archaeology from the beginning (Lyman 2008), but in contrast to many early studies, those of today exhibit a commitment to theory in the scientific sense of the word, and they are designed specifically to examine theoretical implications stemming from formal models (Shennan 2000). But all of those models, whether stated explicitly or not, are built on homology (i.e., a notion of shared ancestry). By definition, how could it be otherwise? Regardless of whether transmission occurs vertically – from parent to child – or horizontally – from peer to peer – it is homologous. As I discuss later, models of social learning, which examine, for example, the kinds of biases that affect the outcomes of transmission, are undeniably useful tools in the social sciences, but they cannot tell us whether traits specific are homologous or analogous to other artifacts. We have to make that distinction on other grounds.

Separating Analogy from Homology

In the late 1960s, Binford (1968:8) identified the lack of a method to distinguish between homologous and analogous cultural similarities as "a basic, unsolved problem" in archaeology. Binford's analytical interest was on function, or analogous similarity, rather than on homologous similarity, but regardless, he needed a means of distinguishing between the two, as was made evident in his debates with Bordes over the nature of Mousterian tool kits from the Dordogne (e.g., Binford 1973). Binford was not the first archaeologist to point out the differences between analogs and homologs in terms that would be familiar to any biologist, nor was he the first to point out the difficulties involved in separating the two empirically. This is what Kroeber (1931:152–153) had to say on the subject:

> There are cases in which it is not a simple matter to decide whether the totality of traits points to a true relationship or to secondary convergence. … Yet few biologists would doubt that sufficiently intensive analysis of structure will ultimately solve such problems of descent. … There seems no reason why on the whole the same cautious optimism should not prevail in the field of culture; why homologies should not be positively distinguishable from analogies when analysis of the whole of the phenomena in question has become truly intensive. That such analysis has often been lacking but judgments have nevertheless been rendered, does not invalidate the positive reliability of the method.

Although Kroeber was clear that there are two forms of similarity – one homologous and the other analogous – he was less than clear as to how the two can actually be distinguished. He suggested that identifying "similarities [that] are specific and structural and not merely superficial … has long been the accepted method in evolutionary and systematic biology" (Kroeber 1931:151), but he offered no advice on how to separate what is "specific and structural" from what is "merely superficial" beyond undertaking a "sufficiently intensive analysis of structure." Exactly what Kroeber meant by that was unstated.

To culture historians such as Kroeber, formal similarities between cultural phenomena signified some kind of ethnic relation – a predictable result of using ethnologically documented mechanisms such as diffusion and enculturation to account for typological similarities in the archaeological record (Lyman et al. 1997). No one realized it, but this was tautological and put the cart before the horse. Thus, Willey's (1953:363) statement that "typological similarity is an indicator of cultural relatedness (and this is surely axiomatic to archaeology), [and thus] such relatedness carries with it implications of a common or similar history" caused little or no concern within the discipline. It might have caused considerable concern because the axiom falls prey to a caution raised by paleontologist George Gaylord Simpson (1961), using monozygotic twins as an example: They are twins not because they are similar; rather, they are similar because they are twins and thus share a common history.

Someone who was writing at the same time when Binford was pointing out the "unsolved problem" in archaeology also understood the need to keep analogous and homologous similarity separate. That someone was David Clarke. As Lee Lyman and I were writing *Applying Evolutionary Archaeology: A Systematic Approach* (O'Brien and Lyman 2000), we reread Clarke's (1968) *Analytical Archaeology* and were again impressed by the insights that he brought to a wide range of topics.[1] One insight was manifest in how he approached the problems of measuring similarity and detecting *heritable continuity* (O'Brien and Lyman 2000) – the notion that B is related to A (a homology) as opposed to simply following A in a historical sequence. Clarke well understood the importance of transmission to maintaining heritable continuity, and he anticipated the arguments of evolutionary archaeology two decades later when he remarked that "it is the artefact maker who feeds back into the phenotypic constitution of the next generation of artefacts the modified characteristics of the preceding population of artefacts, and it is in this way that the artefact population has continuity in its trajectory and yet is continuously shifting its attribute format and dispersion"

(Clarke 1968:181). As Lyman and I pointed out, Clarke explicitly identified Gould's (1991) phenetic–cladistic distinction when he defined *phenetic relationship* as "relationship based on overall affinity assessed on the basis of the attributes of the entities concerned; without any necessary implication of relationship by ancestry" and *phylogenetic relationship* as "relationship by ancestry; transform types from single multilinear time-trajectory, or tradition" (Clarke 1968:229).

Here, the term *tradition* had its basic archaeological meaning – an evolutionary lineage of some, usually unstated, kind – and the term *trajectory* was basically a synonym for tradition, with explicit recognition that it could vary in scale; a trajectory is "the successive sequence of states of an attribute, entity, or vector generated by successive transformations" (Clarke 1968:82). The term *transform type* meant "the relationship existing between successive and collateral type-states from a single multistate artifact-type trajectory" (Clarke 1968:229). In short, a transform was a transition or change, and a transform type was any state of phenomena at a particular time within a lineage. Thus, transform types "are descent related and are really successive or multilineage type-states" (Clarke 1968:211).

Clarke (1968:148) was keenly aware of the reticulate nature of cultural evolution – an issue I discuss later:

> The taxonomic assessment of affinity between entities will suggest the limited number of possible transformation trajectories which might link the network of particular entities in passing time. Great care must then be taken to avoid the danger of interpreting affinity relationships simply as descent relationships – a condition further complicated by the peculiar nature of branch convergence and fusion found in cultural phylogeny.[2] This problem can only be controlled by providing an adequate chronological frame and by postulating multiple alternative hypotheses of development to link the established degree of affinity between sets of entities under investigation.

The model of change that Clarke developed was couched in terms of systems theory, which was popular at the time, but it was remarkably similar to a metaphor for culture change that the mid-twentieth-century American cultural historian James Ford had used. Whereas Ford (e.g., 1952) used the metaphor of a flowing, braided stream, Clarke used the metaphor of a braided cable:

> [W]e have a static model expressing the structure of an artefact-type population as a nucleated constellation of attributes arranged in clustered complexes and secondary nuclei in terms of the attribute intercorrelation in n-dimensional space. We now wish to develop some model of the kinematic trace or time-trajectory "behaviour" of successive generations or phase populations of these artifacts – the phenetic output of one phase being the input of the succeeding phase … . The arbitrarily expressed system trajectory of the developing artefact-type population may be arbitrarily expressed as a single overall integration of such subsystems and lineages within a single multilinear and mosaic development. The archaeological record provides sporadic and successive sections of strands within this continuous cable of development and it is the relative ordering of these sample phase sections in relation to the orientation of the tradition cable that most exercises the archaeologist's researches. (Clarke 1968:210)

Clarke (1968:211) then turned to the problem of concern here:

> One of the fundamental problems that the archaeologist repeatedly encounters is the assessment of whether a set of archaeological entities are connected by a direct cultural

> relationship linking their generators or whether any affinity between the set is based on more general grounds. This problem usually takes the form of an estimation of the degree of affinity or similarity between the entities and then an argument as to whether these may represent a genetic and phyletic lineage or merely a phenetic and non-descent connected affinity.

Clarke then basically reiterated the criteria long used by culture historians for assessing affinity: The more similar two phenomena are, the more characteristics they share, and the more correlations between "idiosyncratic attributes"

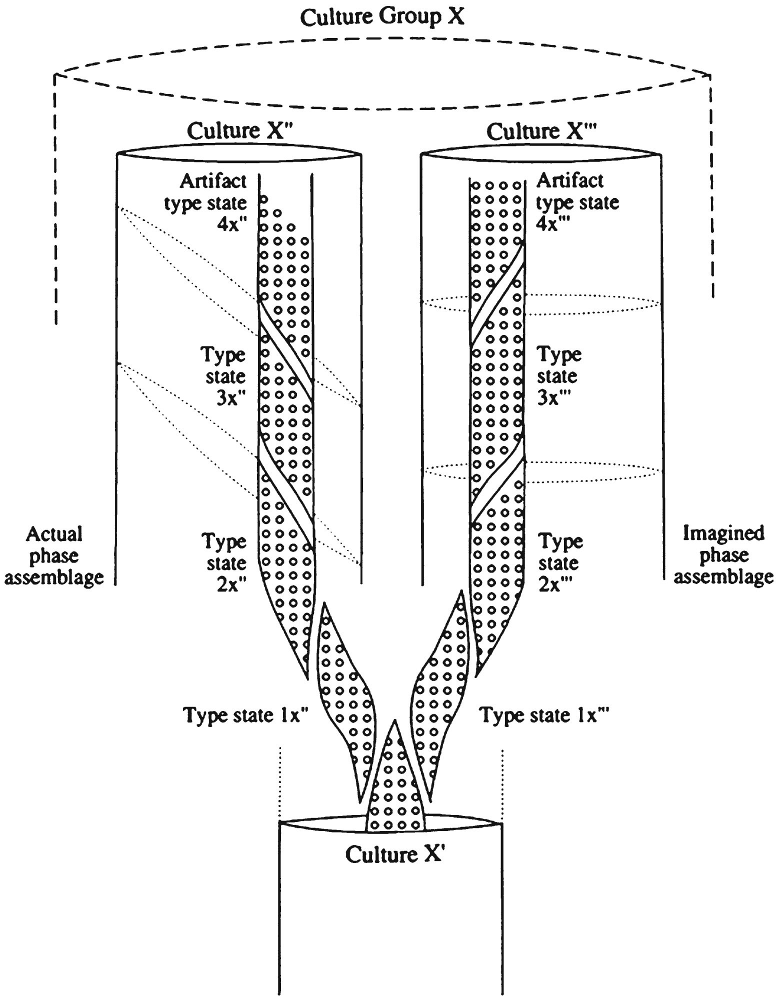

Fig. 14.1 David L. Clarke's (1968) model of culture change. Time may be passing from bottom to top or from top to bottom. Each branch is a lineage, and a "type state" is a cultural unit within a lineage representing an assemblage of classes of unspecified scale. The "actual phase assemblage" spans a duration of time, whereas the "imagined phase assemblage" occupies a point in time, suggesting it was extensionally derived

they share, the stronger the hypothesis of "phyletic relationship" (Clarke 1968:211).

This really wasn't much different than Kroeber's (1931:151) distinction between similarities that are "specific and structural" and those that are "merely superficial." Clarke's real contribution to the issue, in Lyman's and my view, was how he illustrated his model of culture change, a version of which is shown in Fig. 14.1. Clarke's "type states" comprise assemblages of classes of some unspecified scale – attributes of discrete objects, types (attribute combinations) of discrete objects, or assemblages of particular types of discrete objects. An X combined with one or more primes designate each assemblage of material. In our terms, the primes designate a particular lineage; the bottom of the graph comprises lineage X′ and the two branches lineages X″ and X‴. The Arabic numbers denote the sequence of assemblages 1–4, within each of the two branches. Each "type state" comprises, then, a particular cultural unit within a lineage.

Lyman and I suspected that Clarke was signifying the ideational and extensional nature of cultural units with his "imagined phase assemblage" and was distinguishing them from the empirical reality of his "actual phase assemblage." We found this reasonable because he described variation in artifacts as multidimensional, or polythetic, and constantly changing, and Fig. 14.1 shows the "actual phase assemblage" encompassing a time period – the cylinder section is slanted – whereas the 'imagined phase assemblage' encompasses a single point in time – the cylinder section is horizontal. Clarke (1968:46) wrote that a cultural "system is dynamic and continuous, with the attributes or entities [artifact types] having specific values or states which vary by successive transformations". I return to character states and homologous change in a later section, where the discussion turns to replicators and transmission.

As Lycett and Chauhan (Chap. 1, this volume) point out, much of the current archaeological interest in issues of cultural transmission and the phylogenetic histories of cultural traditions owes an intellectual debt both to culture history and to Clarke's *Analytical Archaeology* (O'Brien and Lyman 2000; Shennan 2004), although Clarke's writings could be obtuse at times, and as a result, his take-home message was telegraphed as opposed to being fully explicated.[3] Thus archaeologists failed to appreciate the significant implications of Clarke's model, which rested on the related notions of cultural transmission and heritable continuity. Although he was not in any sense explicit about it, Clarke obviously viewed seriation as a means of testing for heritable continuity – a point my colleagues and I (O'Brien and Lyman 2000, 2003; O'Brien et al. 2001, 2002) have demonstrated empirically, especially with respect to occurrence seriation. If, as we will see later, one can reliably test for heritable continuity, then one can begin to distinguish between analogs and homologs.

Cultural Transmission

Cultural transmission is a primary determinant of behavior, and there is little doubt that it is one of the most effective means of evolutionary inheritance that nature could ever develop. Some (e.g., Gould 1996) argue that culture, through its highly creative transmission processes, has exempted humans from natural selection, and thus from evolution, but a growing number of social scientists are rejecting this myopic view and instead are finding themselves in agreement with Bettinger and Eerkens's (1999:239) claim that "it seems clear to us that cultural transmission must affect Darwinian fitness – how could it be otherwise? And Darwinian fitness must also bear on cultural transmission. Again, how could that not be true? … To deny that would imply that the culturally mediated evolutionary success of anatomically modern humans is merely serendipitous happenstance."

Numerous studies conducted over the past three decades have modeled cultural-transmission processes and the strategies/biases that shape the results of transmission – conformist bias, prestige-based bias, indirect bias, drift, and the like (e.g., Boyd and Richerson 1985; Cavalli-Sforza and Feldman 1981; Eerkens and Lipo 2005, 2007; Henrich 2001; Henrich and Boyd 1998; Henrich and Gil-White 2001). Recent empirical investigations, both in the field and in the laboratory (e.g., Bentley et al. 2004; Bettinger and Eerkens 1999; Eerkens 2000; Eerkens and Lipo 2008; Henrich 2004; Kohler et al. 2004; MacDonald 1998; McElreath et al. 2005; Mesoudi and Lycett 2009; Mesoudi and O'Brien 2008a, b; Shennan and Steele 1999; Shennan and Wilkinson 2001), not only reflect our growing ability to empirically test logical implications of such models but also underscore the variety and complexity of the transmission process (Shennan 2008a, b).

To me, this is one of the most exciting arenas of archaeology, and Paleolithic datasets from both the New World and the Old World have figured prominently in discussions. Bettinger and Eerkens (1999) were, I suspect, the first to apply formal cultural-transmission models to the archaeological record, using projectile points from the Great Basin. There, the bow and arrow replaced the atlatl around A.D. 300–600 – a replacement documented by a reduction in size of stone projectile points. The weight and length of points manufactured after A.D. 600, however, is not uniform across the region. Rosegate points from central Nevada vary little in weight and basal width, whereas specimens from eastern California exhibit significant variation in those two characters.

Bettinger and Eerkens proposed that the variation is attributable to differences in how the inhabitants of the two regions obtained and subsequently modified bow-related technology. In eastern California, bow-and-arrow technology was both maintained and perhaps spread initially through what Boyd and Richerson (1985) referred to as "guided variation," wherein individuals acquire new behaviors by copying existing behaviors and then modifying them through trial and error to suit their own needs. Conversely, in central Nevada bow-and-arrow technology was maintained and spread initially through "indirect bias," a form of learning wherein individuals acquire complex behaviors by opting for a single model on the basis of a particular trait identified as an index of the worth of the behavior. Bettinger and Eerkens proposed that in cases where cultural transmission is through guided variation, human behavior will tend to optimize fitness in accordance with the predictions of the genetic model – individual fitness is the index of success, with little opportunity for the evolution of group-beneficial behaviors. In instances where transmission is through indirect bias, which tends to produce behaviorally homogeneous local populations, conditions may be right for the evolution and persistence of group-beneficial behaviors (Henrich and Boyd 1998; Richerson et al. 2003).

As Shennan and I noted (O'Brien and Shennan 2010), theoretical models are powerful tools, and applications of the models to actual data are why we do science, but controlled "middle-range" experiments provide the necessary bridge between the two (e.g., McElreath et al. 2005; Mesoudi 2008a, b, 2010). In that vein, Mesoudi and I (Mesoudi and O'Brien 2008a, b) designed an experiment to examine the cultural transmission of projectile-point technology, simulating the two transmission modes – indirect bias and guided variation – that Bettinger and Eerkens suggested were responsible for differences in Nevada and California point-attribute correlations. In brief, groups of participants designed "virtual projectile points" and tested them in "virtual hunting environments" with different phases of learning simulating indirectly biased cultural transmission and independent individual learning. As predicted, periods of cultural transmission were associated with significantly stronger attribute correlations than were periods of individual learning. This obviously has ramifications for how one looks at innovation. In simplified terms, more "loners," more innovation; more conformist individuals who want packages off the shelf, less innovation. The experiment and subsequent agent-based computer simulations showed that participants who engaged in indirectly biased horizontal cultural transmission outperformed individual-learning controls (individual experimentation), especially in larger groups, when individual learning is costly and the selective environment is multimodal (Mesoudi 2008b; Mesoudi and O'Brien 2008a, b). This was not unexpected, given Henrich's (2001) finding that biased cultural transmission is the predominant force in behavioral change.

Cultural transmission in a multimodal adaptive landscape, where point-design attributes are governed by bimodal fitness functions, yields multiple locally optimal designs of varying fitness (Mesoudi 2008b, 2009). Mesoudi and I hypothesized that innovations, represented by divergence in point designs resulting from individual experimentation (guided variation), were driven in part by this multimodal adaptive landscape, with different individuals converging by chance on different locally optimal peaks. We then argued that biased horizontal cultural transmission, where individuals copy the most successful person in their environment, allows individuals to escape from these local optima and to jump to the globally optimal peak (or at least the highest peak found by people in that group). Experimental results supported this argument, with participants in groups outperforming individual controls when the group participants were permitted to copy each other's point designs. This finding is potentially important to the production of innovation, as it demonstrates that the nature of the selective environment will significantly affect aspects of cultural transmission (Henrich and Boyd 1998; Mesoudi 2008b, 2010; Toelch et al. 2009).

Cultural Transmission and Lineages

Cultural transmission creates lineages, whether they be lineages of ideas, languages, manuscripts, recipes, or objects. Languages are perhaps the most straightforward cultural datasets for tracing historical patterns of descent (e.g., Gray and Atkinson 2003; Gray et al. 2009; Greenhill et al. 2009; Holden 2002; Rexová et al. 2003) because word retentions and replacements are fairly obvious. The more retentions two languages share, the more closely related they are. This, of course, presupposes that we can remove "loan words" from vocabulary lists. The notion that formal similarity can be used to indicate heritable continuity between cultural phenomena appears to have originated with the use of the comparative method in linguistic studies of the late eighteenth and early nineteenth centuries (Platnick and Cameron 1977). Similarities between the goals of systematic biology and those of historical linguistics have long been noted, dating back at least to the nineteenth century (Wells 1987). Darwin (1859:422) noted the similarity in the *Origin*: "If we possessed a perfect pedigree of mankind, a genealogical arrangement of the races of man would afford the best classification of the various languages now spoken throughout the world; and if all extinct languages, and all intermediate and slowly changing dialects, had to be included, such an arrangement would, I think, be the only possible one." Darwin was speaking of a language taxonomy that resembles the Linnaean taxonomy, but a truer representation is a phylogenetic (historical) tree, which shows ancestors and descendants as opposed to increasingly generalized groups of hierarchically ordered taxa whose historical relationships are obscured (O'Brien and Lyman 2003).

One method that is seeing increased use in formulating hypotheses of cultural descent is cladistics, a set of methods routinely used in biology and paleobiology to construct phylogenetic hypotheses (Collard and Shennan 2008). Like evolutionary taxonomy, cladistics uses only homologous characters to determine phylogeny, but it goes one step further and focuses strictly on "shared derived characters" – those held in common by two or more taxa and their immediate ancestor but no other taxon. In contrast, "shared ancestral characters" are homologous characters held in common by taxa that are related through more than a single ancestor. These are of less use because they do not allow us to order the taxa that have the characters. All we know is that the taxa are somehow related to each other. For example, the presence of a highly complex structure such as a vertebral column is evidence that humans, birds, and literally thousands of other taxa are somehow related. This relatedness is part of the reason for the identification of the subphylum Vertebrata. But the vertebral column is a character that extends so far back in time as to be essentially useless in terms of helping us understand how the myriad backboned organisms of the last 400 million years are related phylogenetically.

To say that cladistics focuses strictly on homologous characters in order to determine phylogeny, and then on only a single kind of homologous character, begs the question of how one sorts homologous characters from analogous characters – those that two or more taxa acquire independently as opposed to through relatedness. As pointed out earlier, this is at least as significant an issue in cultural phylogeny as it is in biological phylogeny, and, like their colleagues who work in the strictly organic world, cultural phylogenists use a number of quantitative methods for identifying and separating homologs from analogs (O'Brien and Lyman 2003). Lycett (Chap. 9, this volume) reviews a number of these; suffice it to say here that these are highly preferable to attempting to identify "similarities [that] are specific and structural and not merely superficial" (Kroeber 1931:151).

Phylogenetic analysis has been used in archaeology to create histories of artifacts and assemblages (e.g., Collard and Shennan 2000; Jordan and Shennan 2003; Tehrani and Collard 2002), and stone tools have figured prominently in much of this work (e.g., Beck and Jones 2007; Buchanan and Collard 2007, 2008; Darwent and O'Brien 2006; Eerkens et al. 2006; Foley 1987; Lycett 2007, 2009; O'Brien and Lyman 2003; O'Brien et al. 2001, 2002). The logical basis for extending cladistics into archaeology is the same as it is in biology: Artifacts are complex systems, comprising any number of replicators, units analogous to genes (Hull 1988). The key word here is "analogous." Although I agree with Richerson et al. (2003:366) that "processes of cultural evolution can behave differently in critical respects from those only including genes," there is considerable merit in viewing artifacts not only as "simple extensions of hands, claws and teeth" (Kuhn 2004:561) but as comprising a hierarchy of replicators (Mesoudi and O'Brien 2008c; O'Brien et al. 2010).

As Hull (1981:32) put it, "a replicator must be small enough to retain its structural pattern through numerous replications, yet large enough to have a structural pattern worth preserving." Pocklington and Best (1997) argue that from an analytical standpoint, appropriate replicators will be the largest units that reliably and repeatedly withstand transmission. Why? There could be two reasons. First, the evolution of smaller units is likely controlled by the transmission of cultural traits defined at a higher level (Shennan 2004). Second, the parallel transmission of multiple smaller-scale units over long periods of time indicates that there is no significant conflict of interest among the subcomponents (Bull 1994). From an evolutionary perspective, parallel transmission is the force that initiates the process by which multiple isolated elements begin to cooperate with one another and create larger-scale structural integrity, which is the scale at which adaptations begin to form.

It is axiomatic in the social sciences that, with rare exceptions, technologies and practices are not reinvented anew each generation; rather, they are learned from other members of society (see papers in O'Brien and Shennan 2010a; Stark et al. 2008). Moreover, technologies are cumulative, which is a hallmark of human culture (Boyd and Richerson 1996). The kinds of changes that occur over generations of, say, stone-tool production are constrained, meaning that new structures and functions almost always arise through modification of existing structures and functions as opposed to arising de novo (Mesoudi and O'Brien 2008c). Ethnographic studies of modern non-industrial peoples suggest that functionally interlinked, recipelike behavioral knowledge is acquired from others through a lengthy period of observation and instruction (Schiffer and Skibo 1987; VanPool et al. 2008). Given such a lengthy period of learning, recipelike behavior is most likely to be acquired from parents, with whom offspring spend most of the time and have more opportunity to observe (Mesoudi and O'Brien 2008c). This is consistent with anthropological evidence that cultural transmission is predominantly vertical in many traditional societies for many traits (e.g., Guglielmino et al. 1995; Hewlett and Cavalli-Sforza 1986; Hewlett et al. 2002; O'Brien et al. 2008; Ohmagari and Berkes 1997), including specific ethnoarcheological evidence for the vertical transmission of material culture (Neff 1992; Shennan and Steele 1999; VanPool et al. 2008). The history of technological changes, which include additions, losses, and transformations, is recorded in the similarities and differences in the complex characteristics of related objects, that is, in objects that have common ancestors. This is what creates the tool "traditions" that are so familiar to archaeologists (Lyman et al. 1997).

Despite the growing number of social scientists who view cladistics as a useful analytical tool, there are outspoken critics of using any phylogenetic method to unravel culture history. So the argument goes, cultural phylogeny is impossible to reconstruct because of the nature of cultural evolution (e.g., Moore 1994; Terrell 2004). Critics view cultural evolution as a vastly different kind of process than biological evolution, with a faster tempo and often a different mode, often referred to as *reticulation.* They argue that the faster tempo and different mode act in concert to swamp most or all traces of phylogenetic history and thus reduce the cultural landscape to little more than a blur of interrelated forms. This line of reasoning is not new: Anthropologists from the late nineteenth century on have recognized that horizontal transmission produces reticulation (Lyman et al. 1997). But it needs to be pointed out that biological evolution can also involve reticulation (Arnold 1997; Jablonka and Lamb 2005), yet the presence of populations of hybrids, or *complex taxa* (Skála and Zrzavý 1994), has not precluded phylogenetic analysis. A key issue here is that critics of cultural phylogenetic analyses have used the term *hybridization* to denote *any* instance of horizontal transmission, and have therefore inappropriately conflated process (hybridization) with mode (reticulation) (O'Brien et al. 2008).

Still, no one ever said untangling phylogenetic histories was easy – a point that applies equally well to biological and cultural datasets. Cultural datasets can be downright messy if not vexing (e.g., Borgerhoff Mulder et al. 2006; Collard and Shennan 2000; Dewar 1995; Eerkens et al. 2006; Hosfield 2009; Nunn et al. 2006; Riede 2009; Terrell 1988), and critics raise valid questions with respect to being able to sort out vertical versus horizontal transmission. One question is whether horizontal transmission mutes a phylogenetic signal to the point where it is undetectable. The answer is "maybe," but it needs to be demonstrated on a case-by-case basis. It is worth pointing out, however, that several studies (e.g., Collard et al. 2006a, b) comparing cultural phylogenies to nonhuman biological phylogenies have found that cultural datasets appear to fit, on average, a tree model equally as well as biological datasets.

An even larger question is, at what scale are we examining transmission? At the scale of the individual? At the scale of the group? At an even larger, more inclusive scale? At the scale of the individual, any social learning that is done outside the parent–offspring will be "noisy" as far as a strict definition of "tradition" goes (VanPool et al. 2008). Oblique transmission, say, from teacher to student, will produce some noise, whereas horizontal transmission between peers will render the signal undetectable. The issue is one of scale. Anthropologists rarely study individuals; their emphasis is on collections of individuals. At the level of the cultural group, purposely left undefined here, it probably doesn't matter who is teaching whom; there is still a phylogenetic signal, which for the sake of simplicity we can call a groupwide "tradition," and it will be distinct from those produced by other cultural groups. It is worth keeping in mind the comment by Borgerhoff Mulder et al. (2006) that when Cavalli-Sforza and Feldman (1981) first used the terms "horizontal" and "vertical" in reference to cultural transmission, they were referring to individuals, not groups. Even vertical transmission at the individual level can produce blending if individuals marry into new groups, just as horizontal transmission can produce branching if it is restricted within groups.

This caveat underscores what several of my colleagues and I (O'Brien et al. 2008) recently pointed out with respect to phylogenetic trees: Although they can be extremely useful for understanding large-scale patterns of cultural transmission, we view them as only one weapon in the anthropologist's toolkit. Other methods – simulation (Nunn et al. 2006), split-decomposition graphs (Bandelt and Dress 1992), tests for serial independence (Abouheif 1999), iterated parsimony (McElreath 1997), network analysis (Cochrane and Lipo 2010; Forster and Toth 2003; Jordan 2009; Lipo 2006), Bayesian methods such as Markov chain Monte Carlo (Huelsenbeck et al. 2000), component analysis (Riede 2009), tests for matrix correspondence (Smouse and Long 1992), assessment of hierarchical cluster structure (Pocklington 2006), and seriation (O'Brien and Lyman 2000) – should be used in tandem with cladistics. To quote Husan and Bryant (2006:254), "even when evolution proceeds in a tree-like manner, analysis of the data may not be best served by forcing the data onto a tree or tree-like mode. Rather, visualization and exploration of the data to discover and evaluate its properties can be an essential first step."

What Might Come Next?

Based on this admittedly brief and nonrandom foray through what I see as some of the interesting work that has been done with respect to cultural transmission and the American Paleolithic, what might it tell us about possible directions of future studies? I would suggest that one fruitful direction would be linking the pattern studies – phylogenetic histories, for example – with the macro- and micro-processes that create them. Here I am not talking so much about specific learning processes – guided variation, indirect bias, and so on – which, as we have seen, structure phylogenetic histories, as I am about evolutionary processes, or modes: *cladogenesis* – the splitting of a taxon into multiple taxa; *anagenesis* – the straight-line evolution of one taxon into another; and *hybridization* – the production of a new taxon as a result of interactions between or among multiple taxa. All three processes exist in both the biological world and the cultural world (O'Brien and Lyman 2000). I view cladogenesis and hybridization as macroevolutionary processes and anagenesis primarily as a microevolutionary process. This follows the way in which the distinction is usually made in biology,

Taxon	I	II	III	IV	V	VI	VII
A	1	⑥	6	①	4	3	6
B	1	4	6	4	4	③	6
C	1	4	⑥	4	4	2	⑥
D	1	4	5	④	4	2	4
E	1	④	5	3	④	2	4
F	1	3	5	③	3	②	4
G	1	3	⑤	5	3	1	4
H	1	3	4	5	③	1	④
I	1	③	4	5	2	①	3
J	1	2	4	⑤	2	4	3
K	1	2	④	2	②	4	3
L	1	2	1	2	5	4	3

Character

Fig. 14.2 Occurrence seriation of 12 taxa (A–L) showing the evolution of character states through time (from O'Brien et al. 2002). Each row is a particular character (I–VII); each Arabic numeral in a column denotes a particular character state. *Circled* character states denote a change from the state immediately below, as if time passed from *bottom* to *top*

where anagenesis is viewed as the production of intraspecific, small-scale changes that organisms go through as they pass from one generation to the next.

We can model microscale changes as in Fig. 14.2, which shows a hypothetical arrangement of twelve projectile-point classes (A–L) and seven character states (I–VII). The classes are in temporal order, with the earliest on the bottom and the latest on the top. In fact, in this example, the classes have been ordered chronologically by occurrence seriation, using the character-state changes [see O'Brien and Lyman (2003) for details]. Circled character states signify a change in state from the preceding class. For example, there are two changes in character state – one in character III (1→4) and another in character V (5→2) – from Class L at the bottom to the next class (K). Importantly, all 12 classes share either five or six character states with their immediate neighbor(s). Given the sequence as constructed, heritable continuity is evident because of considerable overlap in character states across adjacent classes.

Compare Fig. 14.2 with Clarke's model shown in Fig. 14.1. Although he did not use the term "heritable continuity," Clarke implied as much when he wrote that a cultural "system is dynamic and continuous, with the attributes or entities [artifact types] having specific values or states which vary by successive transformations"

(Clarke 1968:46). "Successive transformations" are nothing but replicators doing their work, effecting small change upon small change over varying amounts of time. Anagenesis is a perfectly acceptable term for this kind of change.

What about the tempo of the processes? Is the apparent rapid emergence of a new form – the Clovis point, for example – actually sudden or is it an illusion, meaning that the scale at which we are examining something makes it appear as if the object is new when in actuality it is the product of myriad small-scale cumulative modifications that took place over a relatively long period of time? Again, it becomes both a matter of scale and the amount of time that has elapsed between events of change (at various scales). Equally important, are process and tempo correlated, and if so, how? In paleobiology, the notion of *punctuated equilibrium* (Eldredge and Gould 1972; Gould and Eldredge 1977) was formulated to deal with that correlation, specifically the apparent sudden appearance of new forms. Eldredge and Gould argued that cladogenesis is the general mode under which evolution operates (as opposed to anagenesis) and that rapid cladogenesis is orders of magnitude more important than gradualism as a tempo of speciation. This, again, is a matter of scale and timing. At the scale of species recognition, which is what Gould and Eldredge are talking about, they undoubtedly are correct that rapid cladogenesis is much more important than gradualism. But underlying the eventual rapid splitting event are countless small, slow build-ups of change.

With cultural phenomena, those small build-ups are the result of individual episodes of cultural transmission. Finally, enough build-ups lead to literally a burst of variation, which Schiffer (1996) refers to as *stimulated variation*. Often, these bursts of variation are associated with underlying technological or social changes that make possible new approaches to mitigating perceived deficiencies in a particular design – a process Schiffer (2005) labels as the *cascade effect*. Changes in the context of cultural transmission, "often including the introduction of new cultural traits or shifts in previously unrelated or marginally related cultural traits, fundamentally alter artifact traditions and their selective environments. This creates new adaptive spaces in which artifact traditions change in response to new selective pressures" (Lyman et al. 2009:4).

As an example of how punctuated equilibrium might apply to an archaeological case, Lyman and I (O'Brien 2005, 2007; O'Brien and Lyman 2000) sketched out one possibility with respect to weapon-delivery systems in western North America after roughly 9250 B.C. At issue was the evolutionary placement of point types such as Clovis, Folsom, Meserve, and Goshen and the rapidity with which point types evolved. There is little doubt that point evolution was rapid and, at the scale of point type, cladogenetic. But at a finer level, there is no reason to dismiss anagenesis as a mechanism; after all, it is the small-scale changes – replacements as opposed to splittings – that over time eventually yield large-scale cladogenetic patterns. We know that some of these small-scale changes can result from selection – and that includes biased transmission – whereas others are the result of drift.

Determining whether a character or suite of characters is the product of selection or drift is not always straightforward. In an excellent study that built on Eerkens and Lipo's (2005) analysis of copying error (see also Eerkens and Lipo 2008), Hamilton and Buchanan (2009) found that differences in the size of Clovis points through time and space across North America was the result of an accumulation of stochastic copying error, or drift. Similarly, Morrow and Morrow (1999) proposed that the monotonic increase in "fishtailness" of early fluted points from the Americas was the product not of adaptive convergence but of "stylistic drift … a process inherent in the ongoing translation of cultural practices from one generation to another under specific geographic and historical circumstances" (Morrow and Morrow 1999:227). In another paper, Buchanan and Hamilton (2009) tested Morrow and Morrow's proposition and found support for the drift hypothesis. Despite variation in regional North American environments during the late Pleistocene, apparently not enough time elapsed for local selective gradients to have led to significant changes in Early Paleoindian points.

The paper by Hamilton and Buchanan (2009), which is likely to become a pivotal paper in North American Paleolithic studies, goes a step further than simply testing for drift and links pattern and process in several clever ways. Hamilton and Buchanan posit that Clovis-point technology was a product of strong biased transmission, one product of which was statistically constant variance over time. Biased transmission is recognized as a dominant process of social learning among humans (Henrich 2001), and as Hamilton and Buchanan point out, it is understandable why biased learning strategies would have played a key role in Clovis technologies. Clovis projectile-point manufacture is a complex procedure and would have required a significant amount of investment both in terms of time and energy to learn effectively. Under these conditions, it is likely that there was a significant amount of variation among the level of skill exhibited by tool makers, such that recognized master craftsmen likely would have held considerable prestige. Additionally, in a fast-moving and fast-growing population subject to the widespread environmental changes of the North American late Pleistocene landscape (Hamilton and Buchanan 2007), conformist bias would have been a highly effective strategy for social learning because under circumstances where ecological conditions change is, say, on a generational scale, the mean trait value is often optimal, leading to frequency-dependent bias, or conformism (Henrich and Boyd 1998). However, if ecological conditions change faster, social learning may favor individual trial and error or even a combination of the two (Toelch et al. 2009).

Conclusion

Perhaps the take-home message in all this is found in the success that evolutionary biology enjoyed once the macroevolutionary patterns observed by paleontologists came to be seen as the long-term population-level result of the microevolutionary principles of genetic inheritance found by laboratory geneticists. Huxley (1942) famously labeled this the "Modern Synthesis." We will be led to a similar synthesis in Paleolithic archaeology if we view cultural macro- and micro-evolution within a single overarching framework (Jordan 2009; Lyman and O'Brien 2001; Mesoudi and O'Brien 2009; Mesoudi et al. 2006; O'Brien and Lyman 2000). This means that we view the large-scale patterns observed in the archaeological record as the result not only of specific biases in cultural transmission at the microevolutionary level but also of evolutionary processes such as cladogenesis, anagenesis, and hybridization.

Here is one way to look at it (O'Brien and Lyman 2009): Let's say we are walking toward a large painting and starting to focus on smaller and smaller sections of it. At some distance from the canvas, we can see the entire painting and its overall design; such a macroview is indispensable, but by itself, it obscures details that become apparent only as we get closer and closer to the canvas. At close range we start to see the microstructure – individual brush marks, the layering of paint, and so forth – that undergirds the larger composite. In anthropological terms, those brush marks are the results of individual transmission events that together give rise to the large-scale patterns we see in the archaeological record. Are those microscale results evident in the archaeological record? No, but their proxies are – the billions upon billions of stone tools and the by-products of their manufacture and use that constitute the Paleolithic record.

To return to the point that I used to open this essay, from an evolutionary standpoint, the value of these proxies rests on our ability to sort out analogs from homologs. Some might argue that this is a straw man, that modern archaeology has refined the analytical means to deal with the issue. Maybe, but I'm not convinced that those means are used in all quarters. For an interesting example from the American Paleolithic, take a look at the debate over the reasons behind resemblances between Clovis tools from the United States and Solutrean tools from western Europe. Was there a Solutrean origin for Clovis culture, as Bradley and Stanford (2004) contend, or are the similarities a result of convergence, as Straus et al. (2005) maintain? There is no doubt in my mind – and that of the vast majority of North American archaeologists – that Bradley and Stanford are wrong, but the debate is of interest because it highlights several issues involved in distinguishing between analogs and homologs. With respect to the Clovis–Solutrean issue, there is a barrage of evidence against a homologous relation that overrides the fact that some similarities exist between Solutrean and Clovis stone tools. For example, Native Americans have five major haplogroups in mtDNA and two in the nonrecombining portion of the Y chromosome, which points out an Asian origin for Clovis, not a European one. Further, there are large chunks of Solutrean culture, including rock art, that are missing from Clovis sites. As Straus et al. (2005) point out, for the Solutrean origin of Clovis to make sense, there would had to have been a cultural as well as a genetic amnesia on the part of Solutrean colonists once they arrived on the North American continent.

How many archaeological examples have this kind of "barrage of evidence?" Not many. Most times, we are left with a meager record of tools and the by-products of their manufacture and use. How many times have homologous relations been posited on a whole lot less evidence than what has been brought to bear in the Solutrean–Clovis debate? The number is probably countless. In addition, the two proponents of the Solutrean-origin hypothesis, Bruce Bradley and Dennis Stanford, have seen more Clovis-age tools than most of us combined, and Bradley is an expert flintknapper who knows Clovis stone-tool technology inside and out. If they can be wrong in assessing homologous relations, then that should give us some reason to pause. We might ask ourselves if it wouldn't be better to rely on some of the quantitative methods discussed here rather than on experience and intuition.

Notes

1 Binford (1972) was not quite as impressed with Clarke's book.
2 Recall Kroeber's (1948) depiction of the ever-branching tree of organic evolution versus the reticulate tree of cultural evolution.
3 For a readable account of some of what Clarke proposed, see Shennan (2004).

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References

Abbott, C.C., 1881. *Primitive Industry*. Bates, Salem, MA.
Abouheif, E., 1999. A method for testing the assumption of phylogenetic independence in comparative data. *Evolutionary Ecology Research* 1: 895–909.
Arnold, M.L., 1997. *Natural Hybridization and Evolution*. Oxford University Press, New York.
Bandelt, H.J. and Dress, A.W., 1992. Split decomposition: a new and useful approach to phylogenetic analysis of distance data. *Molecular Phylogenetics and Evolution* 1: 242–252.
Beck, C. and Jones, G.T., 2007. Early Paleoarchaic point morphology and chronology. In *Paleoindian or Paleoarchaic? Great Basin Human Ecology at the Pleistocene–Holocene Transition*, edited by K.E. Graf and D.N. Schmitt, pp. 23–41. University of Utah Press, Salt Lake City.
Bentley, R.A., Hahn, M.W. and Shennan, S.J., 2004. Random drift and culture change. *Proceedings of the Royal Society B* 271: 1443–1450.
Bettinger, R.L. and Eerkens J., 1999. Point typologies, cultural transmission, and the spread of bow-and-arrow technology in the prehistoric Great Basin. *American Antiquity* 64: 231–242.
Binford, L.R., 1968. Archeological perspectives. In *New Perspectives in Archeology,* edited by S.R. Binford and L.R. Binford, pp. 5–32. Aldine, New York.
Binford, L.R., 1972. Contemporary model building: paradigms and the current state of Paleolithic research. In *Models in Archaeology*, edited by D.L. Clarke, pp. 109–166. Methuen, London.
Binford, L.R., 1973. Interassemblage variability – the Mousterian and the "functional argument." In *The Explanation of Culture Change*, edited by C. Renfrew, pp. 227–254. Duckworth, London.
Borgerhoff Mulder, M., Nunn, C.L. and Towner M.C., 2006. Cultural macroevolution and the transmission of traits. *Evolutionary Anthropology* 15: 52–64.
Boyd, R. and Richerson P.J., 1985. *Culture and the Evolutionary Process*. University of Chicago Press, Chicago.
Boyd, R. and Richerson P.J., 1996. Why culture is common, but cultural evolution is rare. *Proceedings of the British Academy* 88: 77–93.
Bradley, B. and Stanford, D., 2004. The North Atlantic ice-edge corridor: a possible Palaeolithic route to the New World. *World Archaeology* 36: 459–478.

Buchanan, B. and Collard, M., 2007. Investigating the peopling of North America through cladistic analyses of Early Paleoindian projectile points. *Journal of Anthropological Archaeology* 26: 366–393.

Buchanan, B. and Collard, M., 2008. Phenetics, cladistics, and the search for the Alaskan ancestors of the Paleoindians: a reassessment of relationships among the Clovis, Nenana, and Denali archaeological complexes. *Journal of Archaeological Science* 35: 1683–1694.

Buchanan, B. and Hamilton, M.J., 2009. A formal test of the origin of variation in North American early Paleoindian projectile points. *American Antiquity* 74: 279–298.

Bull, J.J., 1994. Virulence. *Evolution* 48: 1423–1437.

Cavalli-Sforza, L.L. and Feldman, M.W., 1981. *Cultural Transmission and Evolution*. Princeton University Press, Princeton, NJ.

Clarke, D.L., 1968. *Analytical Archaeology*. Methuen, London.

Cochrane, E.E. and Lipo, C.P., 2010. Network and cladistic analyses of Lapita decoration do not support branching evolution or regional population structure during colonization of Western Remote Oceania. *Philosophical Transactions of the Royal Society B* (in press).

Collard, M. and Shennan, S.J., 2000. Processes of culture change in prehistory: a case-study from the European Neolithic. In *Archaeogenetics: DNA and the Population Prehistory of Europe*, edited by C. Renfrew and K. Boyle, pp. 89–97. McDonald Institute for Archaeological Research, Cambridge.

Collard, M. and Shennan S.J., 2008. Patterns, processes, and parsimony: studying cultural evolution with analytical techniques from evolutionary biology. In *Cultural Transmission and Material Culture: Breaking Down Boundaries*, edited by M.T. Stark, B.J. Bowser, and L. Horne, pp. 17–33. University of Arizona Press, Tucson.

Collard, M., Shennan, S.J. and Tehrani, J., 2006a. Branching versus blending in macroscale cultural evolution: a comparative study. In *Mapping Our Ancestors: Phylogenetic Approaches in Anthropology and Prehistory*, edited by C.P. Lipo, M.J. O'Brien, M. Collard, and S.J. Shennan, pp. 53–63. Aldine, New Brunswick, NJ.

Collard, M., Shennan, S.J. and Tehrani, J., 2006b. Branching, blending, and the evolution of cultural similarities and differences among human populations. *Evolution and Human Behavior* 27:169–184.

Darwent, J. and O'Brien, M.J., 2006. Using cladistics to reconstruct lineages of projectile points from northeastern Missouri. In *Mapping Our Ancestors: Phylogenetic Approaches in Anthropology and Prehistory*, edited by C.P. Lipo, M.J. O'Brien, M. Collard, and S.J. Shennan, pp. 185–208. Aldine, New Brunswick, NJ.

Darwin, C., 1859. *On the Origin of Species by Means of Natural Selection; or the Preservation of Favoured Races in the Struggle for Life*. Murray, London.

Dewar, R.E., 1995. Of nets and trees: untangling the reticulate and dendritic in Madagascar prehistory. *World Archaeology* 26: 301–318.

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

Eerkens, J.W., Bettinger, R.L. and McElreath, R., 2006. Cultural transmission, phylogenetics, and the archaeological record. In *Mapping Our Ancestors: Phylogenetic Approaches in Anthropology and Prehistory,* edited by C.P. Lipo, M.J. O'Brien, M. Collard, and S.J. Shennan, pp. 169–183. Aldine, New Brunswick, NJ.

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

Eerkens, J.W. and Lipo, C.P., 2007. Cultural transmission theory and the archaeological record: providing context to understanding variation and temporal changes in material culture. *Journal of Archaeological Research* 15: 239–274.

Eerkens, J.W. and Lipo, C.P., 2008. Cultural transmission of copying errors and the evolution of variation in Woodland pots. In *Cultural Transmission and Material Culture: Breaking Down Boundaries*, edited by M.T. Stark, B.J. Bowser, and L. Horne, pp. 63–81. University of Arizona Press, Tucson.

Eldredge, N. and Gould, S.J., 1972. Punctuated equilibria: an alternative to phyletic gradualism. In *Models in Paleobiology*, edited by T.J.M. Schopf, pp. 82–115. Freeman, Cooper, San Francisco.

Figgins, J.D., 1927. The antiquity of man in America. *Natural History* 27: 229–239.

Foley, R.A., 1987. Hominid species and stone tool assemblages: how are they related? *Antiquity* 61: 380–392.

Foley, R.A. and Lahr, M.M., 2003. On stony ground: lithic technology, human evolution, and the emergence of culture. *Evolutionary Anthropology* 12: 109–122.

Ford, J.A., 1952. Measurements of some prehistoric design developments in the southeastern States. *American Museum of Natural History, Anthropological Papers* 44: 313–384.

Forster, P. and Toth, A., 2003. Toward a phylogenetic chronology of ancient Gaulish, Celtic, and Indo-European. *Proceedings of the National Academy of Sciences of United States of America* 100: 9079–9084.

Gould, S.J., 1991. The disparity of the Burgess Shale arthropod fauna and the limits of cladistic analysis: why we must strive to quantify morphospace. *Paleobiology* 17: 411–423.

Gould, S.J., 1996. *Full House: The Spread of Excellence from Plato to Darwin.* Harmony, New York.

Gould, S.J. and Eldredge, N., 1977. Punctuated equilibria: the tempo and mode of evolution reconsidered. *Paleobiology* 3: 115–151.

Gray, R.D. and Atkinson, Q.D., 2003. Language-tree divergence times support the Anatolian theory of Indo-European origin. *Nature* 426: 435–439.

Gray, R.D., Drummond, A.J. and Greenhill, S.J., 2009. Language phylogenies reveal expansion pulses and pauses in Pacific settlement. *Science* 323: 479–483.

Greenhill, S.J., Currie, T.E. and Gray, R.D., 2009. Does horizontal transmission invalidate cultural phylogenies? *Proceedings of the Royal Society B* 276: 2299–2306.

Guglielmino, C.R., Viganotti, C., Hewlett, B. and Cavalli-Sforza, L.L., 1995. Cultural variation in Africa: role of mechanisms of transmission and adaptation. *Proceedings of the National Academy of Sciences of United States of America* 92: 7585–7589.

Hamilton, M.J. and Buchanan, B., 2007. Spatial gradients in Clovis-age radiocarbon dates across North America suggest rapid colonization from the north. *Proceedings of the National Academy of Sciences of United States of America* 104: 15629–15634.

Hamilton, M.J. and Buchanan, B., 2009. The accumulation of stochastic copying errors causes drift in culturally transmitted technologies: quantifying Clovis evolutionary dynamics. *Journal of Anthropological Archaeology* 28: 55–69.

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., 2004. 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 the emergence of between-group differences. *Evolution and Human Behavior* 19: 215–241.

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.

Hewlett, B.S. and Cavalli-Sforza, L.L., 1986. Cultural transmission among the Aka Pygmies. *American Anthropologist* 88: 922–934.

Hewlett, B.S., Silvestri, A. de and Guglielmino, C.R., 2002. Semes and genes in Africa. *Current Anthropology* 43: 313–321.

Holden, C.J., 2002. Bantu language trees reflect the spread of farming across Sub-Saharan Africa: a maximum-parsimony analysis. *Proceedings of the Royal Society B* 269: 793–799.

Holmes, W.H., 1893. A question of evidence. *Science* 21: 135–136.

Holmes, W.H., 1897. Stone implements of the Potomac–Chesapeake Tidewater Province. *Bureau of American Ethnology, Annual Report* 15: 13–152.

Hosfield, R., 2009. Modes of transmission and material culture patterns in craft skills. In *Pattern and Process in Cultural Evolution,* edited by S.J. Shennan, pp. 45–60. University of California Press, Berkeley.

Huelsenbeck, J.P., Rannala, B. and Masly, J.P., 2000. Accommodating phylogenetic uncertainty in evolutionary studies. *Science* 288: 2349–2350.

Hull, D. 1981. Units of evolution: a metaphysical essay. In *The Philosophy of Evolution*, edited by U.J. Jenson and R. Harré, pp. 23–44. St. Martin's Press, New York.

Hull, D., 1988. Interactors versus vehicles. In *The Role of Behavior in Evolution*, edited by H.C. Plotkin, pp. 19–50. MIT Press, Cambridge, MA.

Husan, D.H. and Bryant, D., 2006. Application of phylogenetic networks in evolutionary studies. *Molecular Biology and Evolution* 23: 254–267.

Huxley, J.S., 1942. *Evolution, the Modern Synthesis*. Allen and Unwin, London.

Jablonka, E. and Lamb, M.J., 2005. *Evolution in Four Dimensions: Genetic, Epigenetic, Behavioural, and Symbolic Variation in the History of Life*. Bradford, Cambridge, MA.

Jordan, P., 2009. Linking pattern to process in cultural evolution: investigating material culture diversity among the Northern Khanty of northwest Siberia. In *Pattern and Process in Cultural Evolution,* edited by S.J. Shennan, pp. 61–83. University of California Press, Berkeley.

Jordan, P. and Shennan, S.J., 2003. Cultural transmission, language and basketry traditions amongst the California Indians. *Journal of Anthropological Archaeology* 22: 42–74.

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.

Kroeber, A.L., 1931. Historical reconstruction of culture growths and organic evolution. *American Anthropologist* 33: 149–156.

Kroeber, A.L., 1948. *Anthropology* (rev. ed.). Harcourt Brace, New York.

Kuhn, S.L., 2004. Evolutionary perspectives on technology and technological change. *World Archaeology* 36: 561–570.

Lipo, C.P., 2006. The resolution of cultural phylogenies using graphs. In *Mapping Our Ancestors: Phylogenetic Approaches in Anthropology and Prehistory,* edited by C.P. Lipo, M.J. O'Brien, M. Collard, and S.J. Shennan, pp. 89–108. Aldine, New Brunswick, NJ.

Lubbock, J., 1865. *Pre-historic Times, as Illustrated by Ancient Remains, and the Manners and Customs of Modern Savages*. Williams and Norgate, London.

Lycett, S.J., 2007. Why is there a lack of Mode 3 Levallois technologies in East Asia? A phylogenetic test of the Movius-Schick hypothesis. *Journal of Anthropological Archaeology* 26: 541–575.

Lycett, S.J., 2009. Are Victoria West cores 'proto-Levallois'? A phylogenetic assessment. *Journal of Human Evolution* 56: 175–191.

Lyman, R.L., 2008. Cultural transmission in North American anthropology and archaeology, ca. 1895–1965. In *Cultural Transmission and Archaeology: Issues and Case Studies*, edited by M.J. O'Brien, pp. 10–20. Society for American Archaeology Press, Washington, DC.

Lyman, R.L. and O'Brien, M.J., 2001. Misconceptions of evolutionary archaeology: confusing macroevolution and microevolution. *Current Anthropology* 42: 408–409.

Lyman, R.L., O'Brien, M.J. and Dunnell, R.C., 1997. *The Rise and Fall of Culture History*. Plenum, New York.

Lyman, R.L., VanPool, T.L. and O'Brien, M.J., 2009. The diversity of North American projectile-point types, before and after the bow and arrow. *Journal of Anthropological Archaeology* 28: 1–13.

MacDonald, D., 1998. Subsistence, sex, and cultural transmission in Folsom culture. *Journal of Anthropological Archaeology* 17: 217–239.

McElreath, R., 1997. *Iterated Parsimony: A Method for Reconstructing Cultural Histories*. M.A. thesis, Department of Anthropology, University of California, Los Angeles. Los Angeles.

McElreath, R., Lubell, M., Richerson, P.J., Waring, T.M., Baum,W., Edsten, E., Efferson, C. and Paciotti, B., 2005. Applying evolutionary models to the laboratory study of social learning. *Evolution and Human Behavior* 26: 483–508.

Mesoudi, A., 2008a. The experimental study of cultural transmission and its potential for explaining archaeological data. In *Cultural Transmission and Archaeology: Issues and Case Studies*, edited by M.J. O'Brien, pp. 91–101. Society for American Archaeology Press, Washington, DC.

Mesoudi, A., 2008b. An experimental simulation of the "copy-successful-individuals" cultural learning strategy: adaptive landscapes, producer–scrounger dynamics, and informational access costs. *Evolution and Human Behavior* 29: 350–363.

Mesoudi, A., 2010. The experimental study of cultural innovation. In *Innovation in Cultural Systems: Contributions from Evolutionary Archaeology*, edited by M.J. O'Brien and S.J. Shennan, pp. 175–191. MIT Press, Cambridge, MA.

Mesoudi, A. and Lycett, S.J., 2009. Random copying, frequency-dependent copying and culture change. *Evolution and Human Behavior* 30: 41–48.

Mesoudi, A. and O'Brien, M.J., 2008a. The cultural transmission of Great Basin projectile-point technology I: an experimental simulation. *American Antiquity* 73: 3–28.

Mesoudi, A. and O'Brien, M.J., 2008b. The cultural transmission of Great Basin projectile-point technology II: an agent-based computer simulation. *American Antiquity* 73: 627–644.

Mesoudi, A. and O'Brien, M.J., 2008c. The learning and transmission of hierarchical cultural recipes. *Biological Theory* 3: 63–72.

Mesoudi, A. and O'Brien, M.J., 2009. Placing archaeology within a unified science of cultural evolution. In *Pattern and Process in Cultural Evolution,* edited by S.J. Shennan, pp. 21–32. University of California Press, Berkeley.

Mesoudi, A., Whiten, A. and Laland, K.N., 2006. Towards a unified science of cultural evolution. *Behavioral and Brain Sciences* 29: 329–383.

Moore, J.H., 1994. Putting anthropology back together again: the ethnogenetic critique of cladistic theory. *American Anthropologist* 96: 925–948.

Morrow, J.E. and Morrow, T.A., 1999. Geographic variation in fluted projectile points: a hemispheric perspective. *American Antiquity* 64: 215–230.

Neff, H., 1992. Ceramics and evolution. *Archaeological Method and Theory* 4: 141–193.

Nunn, C.L., Borgerhoff Mulder, M. and Langley, S., 2006. Comparative methods for studying cultural trait evolution: a simulation study. *Cross-Cultural Research* 40: 177–209.

O'Brien, M.J., 2005. Evolutionism and North America's archaeological record. *World Archaeology* 37: 26–45.

O'Brien, M.J., 2007. What's new? Some basic issues in anthropological studies of innovation. *Review of Archaeology* 28: 39–54.

O'Brien, M.J., Darwent, J. and Lyman, R.L., 2001. Cladistics is useful for reconstructing archaeological phylogenies: Palaeoindian points from the southeastern United States. *Journal of Archaeological Science* 28: 1115–1136.

O'Brien, M.J. and Lyman, R.L., 2000. *Applying Evolutionary Archaeology: A Systematic Approach*. Kluwer Academic/Plenum, New York.

O'Brien, M.J. and Lyman, R.L., 2003. *Cladistics and Archaeology*. University of Utah Press, Salt Lake City.

O'Brien, M.J. and Lyman, R.L., 2009. Darwinism and historical archaeology. In *International Handbook of Historical Archaeology*, edited by T. Majewski and D. Gaimster, pp. 227–252. Springer, New York.

O'Brien, M.J., Lyman, R.L., Collard, M., Holden, C.J., Gray, R.D., and Shennan, S.J., 2008. Phylogenetics and the evolution of cultural diversity. In *Cultural Transmission and Archaeology: Issues and Case Studies*, edited by M.J. O'Brien, pp.39–58. Society for American Archaeology Press, Washington, DC.

O'Brien, M.J., Lyman, R.L., Mesoudi, A., and VanPool, T.L., 2010. Cultural traits as units of analysis. *Philosophical Transactions of the Royal Society B* (in press).

O'Brien, M.J., Lyman, R.L., Saab, Y., Saab, E., Darwent, J., and Glover, D.S., 2002. Two issues in archaeological phylogenetics: taxon construction and outgroup selection. *Journal of Theoretical Biology* 215: 133–150.

O'Brien, M.J. and Shennan, S.J., (eds.) 2010a. *Innovation in Cultural Systems: Contributions from Evolutionary Anthrapology*. MIT Press, Cambridge, MA.

O'Brien, M.J. and Shennan, S.J., 2010b. Issues in anthropological studies of innovation. In *Innovation in Cultural Systems: Contributions from Evolutionary Anthrapology*, edited by M.J. O'Brien and S.J. Shennan, pp.3–17. MIT Press, Cambridge, MA.

Ohmagari, K. and Berkes, F., 1997. Transmission of indigenous knowledge and bush skills among the Western James Bay Cree women of subarctic Canada. *Human Ecology* 25: 197–222.

Platnick, N.I. and Cameron, D., 1977. Cladistic methods in textual, linguistic, and phylogenetic analysis. *Systematic Zoology* 26: 380–385.

Pocklington, R., 2006. What is a culturally transmitted unit, and how do we find one? In *Mapping Our Ancestors: Phylogenetic Approaches in Anthropology and Prehistory*, edited by C.P. Lipo, M.J. O'Brien, M. Collard, and S.J. Shennan, pp.19–31. Aldine, New Brunswick, NJ.

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

Rexová, K., Frynta, D. and Zrzavý, J., 2003. Cladistic analysis of languages: Indo-European classification based on lexicostatistical data. *Cladistics* 19: 120–127.

Richerson, P.J., Boyd, R.T. and Henrich, J., 2003. Cultural evolution of human cooperation. In *Genetic and Cultural Evolution of Cooperation,* edited by P. Hammerstein, pp. 357–388. MIT Press, Cambridge, MA.

Riede, F., 2009. Tangled trees: modeling material culture evolution as host–associate cospeciation. In *Pattern and Process in Cultural Evolution,* edited by S.J. Shennan, pp. 85–98. University of California Press, Berkeley.

Schiffer, M.B., 1996. Some relationships between behavioral and evolutionary archaeologies. *American Antiquity* 61: 643–662.

Schiffer, M.B., 2005. The devil is in the details: the cascade model of invention processes. *American Antiquity* 70: 485–502.

Schiffer, M.B. and Skibo, J.M., 1987. Theory and experiment in the study of technological change. *Current Anthropology* 28: 595–622.

Shennan, S., 2000. Population, culture history, and the dynamics of culture change. *Current Anthropology* 41: 811–835.

Shennan, S., 2004. Analytical archaeology. In *A Companion to Archaeology*, edited by J. Bintliff, pp.3–20. Blackwell, Oxford.

Shennan, S.J., 2008a. Canoes and cultural evolution. *Proceedings of the National Academy of Sciences of United States of America* 105: 3175–3176.

Shennan, S.J., 2008b. Evolution in archaeology. *Annual Review of Anthropology* 37: 75–91.

Shennan, S.J. and Steele, J., 1999. Cultural learning in hominids: a behavioural ecological approach. In *Mammalian Social Learning: Comparative and Ecological Perspectives*, edited by H.O. Box and K.R. Gibson, pp. 367–388. Cambridge University Press, Cambridge.

Shennan, S.J. and Wilkinson, J.R., 2001. Ceramic style change and neutral evolution: a case study from Neolithic Europe. *American Antiquity* 66: 577–594.

Simpson, G.G., 1961. *Principles of Animal Taxonomy*. Columbia University Press, New York.

Skála, Z. and Zrzavý, J., 1994. Phylogenetic reticulations and cladistics: discussion of methodological concepts. *Cladistics* 10: 305–313.

Smouse, P.E. and Long, J.C., 1992. Matrix correlation analysis in anthropology and genetics. *Yearbook of Physical Anthropology* 35: 187–213.

Stark, M.T., Bowser, B.J. and Horne, L., (eds.), 2008. *Cultural Transmission and Material Culture: Breaking Down Boundaries*. University of Arizona Press, Tucson.

Straus, L.G., Meltzer, D.J., and Goebel, T., 2005. Ice age Atlantis? Exploring the Solutrean–Clovis 'connection.' *World Archaeology* 37: 507–532.

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

Terrell, J.E., 1988. History as a family tree, history as an entangled bank: constructing images and interpretations of prehistory in the South Pacific. *Antiquity* 62: 642–657.

Terrell, J.E., 2004. Review of "Cladistics and Archaeology" by M.J. O'Brien and R.L. Lyman. *Journal of Anthropological Research* 60: 303–305.

Toelch, U., van Delft, M.J., Bruce, M.J., Donders, R., Meeus, M.T.H., and Reader, S.M., 2009. Decreased environmental variability induces a bias for social information use in humans. *Evolution and Human Behavior* 30: 32–40.

VanPool, T.L., Palmer, C.T., and VanPool, C.S., 2008. Horned serpents, tradition, and the tapestry of culture. In *Cultural Transmission and Archaeology: Issues and Case Studies*, edited by M.J. O'Brien, pp.77–90. Society for American Archaeology, Washington, DC.

Wells, R.S., 1987. The life and growth of language: metaphors in biology and linguistics. In *Biological Metaphor and Cladistic Classification*, edited by H.M. Hoenigswald and L.F. Wiener, pp. 39–80. University of Pennsylvania Press, Philadelphia.

Willey, G.R., 1953. Archaeological theories and interpretation: New World. In *Anthropology Today*, edited by A.L. Kroeber, pp. 361–385. University of Chicago Press, Chicago.