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INTERPRETING LITHIC TECHNOLOGY UNDER THE EVOLUTIONARY TENT

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An underlying theme of this volume is that lithic technological analysis is not well integrated with a theoretical approach, and that evolutionary theory has great potential to fill this void. This is not to say that evolutionary concepts and models have not been used by archaeologists who have been working with lithic technological data. In fact a number of recent volumes have been published recently that are dedicated to the application of specific evolutionary concepts to lithic data. Surovell's (2009) book, *Toward a Behavioral Ecology of Lithic Technology*, is a good example. The edited volume by Michael O'Brien (2008), *Cultural Transmission and Archaeology*, draws on many lithic data case studies. A number of highly regarded and well cited journal articles that have applied specific evolutionary approaches to lithic technology (Beck et al. 2002; Bettinger and Eerkens 1999; Brantingham 2003; Mesoudi and O'Brien 2008; O'Brien et al. 2001; and others). This volume attempts to bring together several different evolutionary perspectives and lithic technology. We invited research contributions from a number of scholars who have been standing on different sides of a theoretical fence at one time or another, but have all embraced Darwinian evolutionary approaches and in this case use lithic technology in that effort.

The chapters included in this collection use lithic artifacts or artifact characteristics as an empirical proxy for past human land-use strategies and/or past human behaviors that apply an evolutionary theoretical foundation to help interpret those data. Even though all of the chapters in this volume emphasize

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evolutionary approaches and lithic technological systems, the amount of theoretical diversity within the volume is quite striking. The chapters cover a range of topics beneath a broad evolutionary umbrella including but not limited to human behavioral ecology (HBE), cultural transmission, phylogenetic analysis, risk management, macroevolution, dual inheritance theory, cladistics, central place foraging, costly signaling, selection, drift and various applications of evolutionary ecology. Some of these evolutionary approaches have not always completely agreed with one another. However, we believe that within this group of studies there is a strong common ground for multiple approaches to Darwinian thinking. In some chapters we see an intentional blending of multiple evolutionary approaches towards the study of lithic technology. In other chapters we intentionally point out areas that we believe represent like-minded thinking from different evolutionary models, even if authors may not have intentionally made such linkages.

This assemblage of chapters is structured in a way that segregates the volume contributions into three very broad thematic topics: phylogenetic evolution, HBE, and cultural transmission. However, many of the chapters in this volume could have been placed into more than one of these themes and we hope authors and readers are comfortable with our distribution. The fact that so many of the chapters could be included in multiple sections again points to our underlying impression that there is increasingly more common ground rising under the evolutionary umbrella in archaeology. It became evident to us that a number of crosscutting issues and data sets joined chapters from different themes. Four of the chapters (Beck and Jones; Kuhn and Miller; Shott; and VanPool et al.) explored evolutionary applications with North American Paleoindian projectile technology. Four chapters (Bettinger et al.; Kuhn and Miller; Stevens; Goodale et al.) examined retouch intensity in some form or another. Two of the chapters used experimental replication of artifacts to assess evolutionary models (Clarkson et al.; Goodale et al.). Four chapters focused on lithic raw material provenance in some form (Beck and Jones; Bettinger et al.; Ferris; Garvey). Of course, all chapters use evolutionary approaches along with some aspect of lithic technology.

We also hope this volume will inspire lithic researchers to apply their data, whether generated experimentally, collected from region surveys, or excavated from detailed stratigraphy, to more problem oriented approaches to analysis and interpretation.

We feel that the context of an archaeological study (particularly lithic study) is extremely important for understanding the kinds of activities that have occurred at a particular location or within a particular region. However, the value of that specific context can often be measured only by the extent to which it is abstracted to more generalized interpretations. In some lithic studies, strict emphasis on context provides little more than a detailed description of artifacts and their associations with one another and their environment. In other studies the lack of context and emphasis on abstract associations of data result in little more than untested hypotheses and speculations about what could or might have happened in past times on sites and within regions. We believe this volume emphasizes both ends of this spectrum and hope our examples show how lithic technological data can be tied to evolutionary theory to build stronger interpretations of past human activities.

CULTURE HISTORY, LITHIC DATA, AND PHYLOGENETIC EVOLUTION

If we acknowledge that evolution is defined simply as descent with modification (Lyman and O'Brien 1998), and that evolutionary approaches deal with historical phenomenon (Boyd and Richarson 1992; Jones et al. 1995; Lipo et al. 2006), then cultural-historical studies associated with lithic assemblages provide a common heritage for the various components of evolutionary thought in archaeology and lithic studies. Archaeologists have been arranging artifact types and assemblages into chronologies since before the use of radiocarbon dating (Krieger 1944; McKern 1939; Ritchie 1944; Witthoft 1949) and the practice continues today (Beck and Jones 2010; Ramenofsky 2009; Sellet et al. 2009). The structuring of lithic types and assemblages into historical sequences based on similarities of form and compositions, respectively, is a form of phylogenetic analysis not substantially different from what takes place in paleoecology. Early chronological studies of stone tool assemblages were explicit about the relationships between different types over time. There was an attempt to show that similarity of form represented lineal descent with modification. This is evident in Jesse Jennings' discussion of the Plano big game hunting tradition. He notes (1968:123), "If typological evidence is to be accepted, one can see a continent-wide dispersal of Big Game Hunters by, or earlier than 10,000 B.P.…In all areas, however, the tradition of the lanceolate blade or point, fluted or unfluted, first coexists with, and finally becomes part of, the next widespread and long-lived stage called the Archaic." That similarity of artifact form over time and space represents common ancestry is an evolutionary notion. As noted by Neiman (1995:31), "Culture history was grounded in the interpretation of the record in terms of homologous similarity."

Cultural chronologies of this kind were swept into the evolutionary literature in archaeology under the wing of the selectionist movement (also identified as evolutionary archaeology) that can be equated roughly with the work of Dunnell (1978, 1980, 1982) and his followers (Jones et al. 1995; Leonard and Jones 1987; Lyman and O'Brien 1998; O'Brien and Holland 1990, 1992; O'Brien and Lyman 2000; O'Brien et al. 1998). They define evolutionary archaeology as change in the composition of a population over time. "In evolutionary archaeology, the population is artifacts, which are viewed as phenotypic features, and

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it is the differential representation of variation at all scales among artifacts for which it seeks explanations" (Lyman and O'Brien 1998:616). Evolutionary archaeology involves "(1) measuring variation – that is, dividing it into discrete sets of empirical units...; (2) tracking variation through time and across space to produce a historical narrative about lineages or particular variants; and (3) explaining the differential persistence of individual variants comprising lineages in particular time-space contexts" (O'Brien et al. 1998:487). The selectionist paradigm takes the work of culture historical archaeologists and applies heritable continuity to the temporal sequence of artifacts. They, like paleobiologists they emulate, attempt to distinguish between analogous and homologous characteristics to assess degree of relatedness.

Some of the early research in this area dealing with lithic technology can be seen in the scraper study by Meltzer (1981). He attempted to separate aspects of stylistic variability from functional variability with the underlying notion that stylistic variability is viewed as nonselective or homologous (see Dunnell 1978:199). His study recognized scraper characteristics on stone tools for times and places around the world that had little possibility of heritable linkages. In doing so, he was able to establish those characteristics as functional attributes of the tools. "So far as I can tell, given the variables I selected, the sample size, and the particular time/space coordinates of data, there is no stylistic component in the morphology of the tools examined" (Meltzer 1981:326). The separation of style and function in materials is a fundamental distinction for the selectionist approach in archaeology. "Those units that are functional will be sorted by natural selection; those that are stylistic will be sorted by the vagaries of transmission" (O'Brien et al. 2003:576).

The integration of stone tool analysis within the evolutionary framework of selectionism increased in frequency with the adoption of systematic measures of phylogenetic analysis known as cladistics. Put rather simply, cladistics is a form of phylogenetic mapping that uses derived characteristics to construct phylogenies (Mayr 1982). Such analysis is often displayed in the form of a branching tree or cladogram. In a cladogram taxa are organized into groups or clusters based on shared derived characters. Any taxon in the population that does not share a derived character is graphed alone as an out group. In this way the cladogram shows the historical relationship of taxa and identifies the attributes or characters that link the various taxa (Buchannan and Collard 2008).

Foley used cladistics on stone tool assemblages to establish relatedness among early hominids (Foley 1987; Foley and Lahr 2003). Lyman and O'Brien (2000) applied clade-diversity approaches to understanding projectile point variation from Gatecliff Shelter in Nevada. Their analysis showed that projectile point diversity at the site may have resulted from an increase in the number of weapon delivery systems. Others using different kinds of lithic analysis suggest the same results (Beck 1995; Hughes 1998). This type of analysis was applied to Paleoindian projectile technology from the southeastern United States to establish relationships among Paleoindian technologies and later Archaic technologies (Darwent and O'Brien 2006; O'Brien et al. 2001). The Paleoindian example was expanded to explore human peopling of North America using cladistics (Buchanan and Collard 2007, 2008; Buchanan and Hamilton 2009). Others use cladistic approaches to assess phylogenetic relationships between bow and arrow technology and dart technology (Lyman et al. 2008, 2009).

There have been many critics of the selectionist position with regard to using artifacts as phylogenetic markers in the same way that paleontologists use fossil bones to reconstruct phylogenetic trees of ancient members of the animal kingdom (e.g. Bamforth 2002; Boone and Smith 1998; Fitzhugh 2001; Gabora 2006; Shennan 2002), and there has been ample reply to such criticism (O'Brien and Lyman 2002; O'Brien et al. 2003). Though exploring differences and similarities between various ideological camps under the evolutionary umbrella is outside the scope of this book, we do think there has been an increasing amount of common ground between camps. For instance, Bamforth (2002) argued that variation in material culture (artifacts) may be conditioned by a number of different agencies, such as culture and human behavior. He suggested that not all variation in human artifacts over time may be representing evolutionary trends in the same way that paleontologists see evolutionary trends in ancient fossils. We feel that some archaeologists who use phylogenetic analysis of artifacts also embrace this position or have come to embrace it.

Chapter 2 by Lyman explores graphic representation of artifact variation over time to help illuminate evolutionary processes. He demonstrates several important characteristics of graph styles. For instance, he graphs projectile point data to show relative abundance of types (richness) over time (displayed by strata) is a good reflection of the Darwinian variational model of evolution. That model shows changes in frequencies of types over time and not changes in types. When variation in attributes of point types is displayed over time we can see how formal variation of the population is being altered or incorporated into the types. Indeed, graphic styles show important and distinct aspects of artifact variation. However, our "take away" point here is Lyman's recognition of different processes associated with different aspects of lithic artifacts. He emphasizes that graphed patterns and their inferred processes depend on the classificatory units used in the analysis. He notes, "…those units of measurement, that are graphed, whether types of points, length of points measured in centimeters or millimeters, or neck width measured in millimeters or tenths of millimeters. Not just knowing the identity of the graphed units, but understanding what those units actually are, would seem to be a critical step in the production of graphs that are correctly perceived and subject to a minimum of misinterpretation (or misperception)." In our opinion, this is what Bamforth (2002:448) was advocating for with regard to variation in artifact form in stating, "…I have argued here that archaeology's essentially universal reliance on aggregate data sets that represent the activities of human groups whose familial and reproductive relations are unknown currently precludes us from making such a contribution. It may be possible to develop modes of analysis that allow us to surmount this problem, but we have certainly not yet accomplished this." We think Lyman's study goes a long way towards understanding and developing such modes of analysis. As a result we see some common ground here.

Another aspect of the Lyman chapter we think is critical here especially with regard to lithic studies and phylogenetic analysis is the recognition of what we call "context of variation." Lyman correctly notes, "A graphed temporal sequence of archaeological data does not necessarily imply evolution, regardless of pattern or process." This is echoed in Chapter 3 by Shott, which recognizes that projectile points change as a result of multiple processes (use, functional requirements, human situational needs). These sources of morphological variation need to be understood before practitioners of phylogenetic lithic analysis graph or even select artifact attributes for phylogenetic study. "Cladistic analysis may plot the sequence of change, but only detailed contextual study can explain it" (Shott 2008:150). We could not agree more with Shott (and by extension Lyman) on this issue. If archaeologists are interested in characterizing evolutionary trends such as descent with modification in artifact forms it is critical that we select the appropriate attributes to show phylogenetic relationships. It may not be appropriate simply to use whatever attributes are available.

Not all attributes or types produced from attributes represent lineal decent. It is important to understand some of the production, use, maintenance and reuse processes that influence the morphological variability found in stone tools before plugging tool attribute variability into clustering algorithms. For instance, phylogenetic projectile point typologies are meant to show character states that are the result of shared ancestry derived from the ancestral state for the type. This is why we can effectively use projectile point typologies to describe cultural-historical sequences. However, if the projectile point typologies are built or assessed by morphological characteristics that do not vary by descent and are not derived from an ancestral state, there is a good chance we will be barking up the wrong phylogenetic tree. This is relatively easy to visualize with morphological characters associated with phenomena we understand well. If we were interested in describing the phylogenetic history of Alaskan Dall sheep (*Ovis dalli dalli*) based on skeletal remains we probably would not measure horn curl length, knowing that (in male sheep) it correlates positively with the age of the individual animal and is directly related to the life history of the individual organism. We know this through observations of contemporary Dall sheep and through studies charting the growth of horn curl and age at time of death. Foot structure and overall body size have more to do with historical lineages of the species than horn curl length. In the same way, we know that some types of projectile points have blades that are altered and changed throughout the period of time they are used by ancient humans. Figure 13.1 in Chapter 13 by Goodale et al. shows variation in blade shape reflected in stages of projectile point production and use, taken from Al Goodyear's (1974) study of Dalton Points from the Brand Site. This was among the first studies to demonstrate how blade shape and size on projectile points were reduced from use and resharpening. Others have more recently demonstrated such morphological changes on a variety of projectile point styles using both experimental resharpening studies and analysis of allometric characteristics from excavated collections (Ahler and Geib 2000; Andrefsky 2006; Bement 2002; Kuhn and Miller this volume; Shott and Ballenger 2007; Truncher 1990). If projectile point blade elements change size and shape during their use-life it is not reasonable to use this characteristic of projectile points to chart decent. Such measurements are akin to charting Dall sheep lineages based on horn curl length without knowing that horn curl length changes during the lives of individual sheep. Projectile points are not the only stone tools that undergo changes during their use lives. Stone scrapers, knives, and blades have been shown to change morphology as a result of use and resharpening (Goodale et al. 2010; Hiscock and Attenbrow 2003; Hiscock and Clarkson 2007; Clarkson 2002). As Lyman (Chapter 2 and preceding text) notes, it is important to understand the units we are measuring. It is little wonder that Shott (Chapter 3) when referring to projectile point characteristics used in phylogenetic analysis says, "The phylogenetic method used, common in cladistic studies, produced parsimonious cladograms that matched none of the outcomes predicted by any hypothesis, even the one favored."

Chapter 3 by Shott has been mentioned several times in this section. His contribution emphasizes details that are worth considering in phylogentic analysis of lithic artifacts. However, he does more than identify problem areas. He suggests that archaeology needs to embrace a new theoretical perspective and suggests another evolutionary approach used in the biological sciences, morphometrics. Shott describes how morphometrics can overcome many of the analytical problems associated with other phylogentic strategies when dealing with lithic technology. He also eloquently advocates for an archaeological theory that focuses on form and pattern of material culture: one that explains variance and change, and allows for an explanation of mode, rate and causes of change in our materials. We feel Shott's ideas are perfectly aligned with the challenges of lithic technology and fit well under the umbrella of evolutionary thought.

HUMAN BEHAVIORAL ECOLOGY, TOOL USE-LIFE, AND RAW MATERIAL PROVENANCE

Roughly simultaneous with the selectionist genre of evolutionary approaches in lithic technological studies was the adoption of evolutionary ecology or behavioral ecology. Evolutionary ecology attempts to explain cultural and behavioral change as forms of phenotypic adaptation to varying social and ecological conditions (Boone and Smith 1998:141). Evolutionary ecologists assume that natural selection has designed organisms to respond to local conditions in ways that increase their fitness (Winterhalder and Smith 1992). Some archaeologists separate evolutionary ecology and behavioral ecology, where "Behavioral ecology is that subset of evolutionary ecology concerned with accounting for the evolution and adaptive character of behavior" (Fitzhugh 2001:129). In either case, phenotypic variability (including behavior) is constrained by natural selection to seek fitness propagating solutions. Models of behavior (fitness maximizing behavior) are then developed in local ecological contexts and are tested against the archaeological record (Boone 1992; O'Connell 1995).

The lithic technological literature is full of such evolutionary ecological approaches dealing with risk (Bousman 2005; Clarkson 2008; Fitzhugh 2001; Shott 1996; Torrence 1983), production strategies (Andrefsky 1994; Brantingham et al. 2000; Jeske 1989; Clarkson 2008), optimization (Bamforth 1986; Bleed 1986; Goodale et al. 2008; Kelly 1988; Tomka 2001), and residential mobility (Brantingham 2006; Lurie 1989; Parry and Kelly 1987; Shott 1986). Much of the early and contemporary evolutionary ecology research dealing with lithic technology used fairly informal modeling that stresses the association of two or more variables. For instance, many studies emphasize lithic raw material transport costs as an independent parameter for or against a dependent variable such as stone tool technology (Bamforth and Becker 2000; Kuhn 2004). Other studies emphasize the relationship between technology and relative residential sedentism (Kelly and Todd 1988; Wallace and Shea 2006). Such simplistic modeling has been criticized as "nonevolutionary" on the grounds that it does not reference evolutionary forces to explain change (Abbott et al. 1996). However simplistic the modeling, such studies attempt to show causal relationships between two or more factors and they tend to place their studies within a historical context to explain change or stasis over time. Explanations of phenomena do not need to be posed in evolutionary contexts to be related to the processes of evolution. Bettinger and Richarson provide a good example of just such a case (1996:224):

> Thus the question posed to a physiologist, "Why is this dog panting"? Is more appropriately and directly answered by saying "To regulate its body

temperature," than by a protracted explanation involving the evolution and natural history of dogs and warm-bloodedness. In responding without direct reference to evolutionary processes, the physiologist does not question that this panting is the result of a long evolutionary history.

The point here is that explanations may be only functional do not mean they are not useful in an evolutionary context or understanding an evolutionary process. The evolutionary biologist, Ernst Mayr (1982:89–90) was clear about this when he applied *Allen's rule* to explain size difference in ravens from the Arctic and equatorial zones. Body size is larger and extremity size is smaller in colder than in warmer climates. This is a functional explanation associating climate with body size characteristics. Mayr does not explain the process of natural selection within each environment as it relates to the raven's circulatory system.

Several contributions to this volume use formal and less formal models of evolutionary ecology to address lithic artifact data. One of the most ingenious applications of evolutionary ecology to lithic data is the Kuhn and Miller (Chapter 10) study. They actually attempt to unite the field of "lithic technological organization" and evolutionary ecology. Kuhn and Miller use the "patch choice" model developed by Charnov (1976) and apply the Marginal Value Theorem (MVT) to stone tool data in an effort to determine when stone tools should be discarded or abandoned (see also Surovell 2009). In this study they apply the MVT to projectile point life histories. They essentially conceptualize lithic artifacts as patches of utility. The amount of utility contained in each artifact is limited and utility for many artifacts should decline over time as the artifacts are increasingly used and worn out.

The model is applied to a set of Paleoindian projectile points from Tennessee. Utility is measured simply by the amount of correlation between projectile point type lengths and widths based on the assumption that newly manufactured points begin their use-lives with fairly standardized shapes. As blades and tips are resharpened or refreshed after use and damage, the types should show less correlation between the two variables. Results of their study show that discard patterns of Paleoindian points in Tennessee changed from the earlier to the later times. The MVT model suggests that projectile points were discarded later in their use-lives because of increased cost of replacement or because of a decline in average return from use of points. Both explanations conform to the model expectations. The second possibility is unexpected given traditional interpretations of lithic technological organization and suggests that formal modeling of stone tools may be a productive direction for lithic analysis to help explain patterning in the record.

Chapter 7 by Clarkson et al. also adopts optimality modeling using the MVT. Again in this case, lithic tools are used as patches of utility. And again, utility is contrasted with the amount of retouch. However, in the Clarkson et al. study, utility is empirically calculated on stone tool scrapers by the amount of wood removed by each scraper in a series of experiments. Three kinds of wood scraping tools are assessed for utility: (1) unhafted unretouched flake tools, (2) hafted unretouched flake tools, and (3) unhafted retouched flake tools. Surprisingly, unretouched and unhafted flake tools are found to be the most efficient scraping tools when compared to the other two forms. The authors state, "The main conclusion this study reached is that prehistoric tool users should in many cases only have retouched their woodworking toolkits when replacement material was scarce and/or unpredictable or when manufacturing costs were high (e.g. hafting)." Interestingly, use of this model in association with experimental data directly measuring tool efficiency has confirmed some of the less formalized evolutionary models often associated with lithic technological studies such as the Parry and Kelly (1987) model of expedient and formalized tools. Both Clarkson et al. (Chapter 7) and Kuhn and Miller (Chapter 10) have extended implications of less formalized technological modeling by using more formalized models associated with evolutionary ecology.

Chapter 6 by Bettinger et al. takes optimality modeling a step farther and models technological investment as a relationship between tool manufacturing time plus resource procurement time against resource procurement rate (based on previous work of Bettinger et al. 2006 and Ugan et al. 2003). Simply put, the model predicts that when resources are abundant, time spent in procurement will be low, and the less costly technology is superior. This conforms to what Clarkson et al. (Chapter 7) found with regard to unretouched versus retouched or hafted tools. The less costly technology was more effective and should have been selected, given all else was equal. However, Bettinger et al. also predict that when resources are scarce, time spent in procurement will be high, and the more costly technology will be superior. In other words, groups under the most resource stress will display the most costly refinements of the most costly technology. Bettinger et al. apply their model predictions to the stone tool industry of millet farming aboriginal peoples of a remote section of North China. Among other things, they conclude that millet farming was introduced to this marginal environment by a migrant population into the region and that the costly microlithic or "nanolithic" technology was extremely costly. Again, formalized models associated with optimal foraging are used to help explain not only aspects of technological differences, but also how behavioral, economic, or subsistence variability may be related to the technological shifts.

One area of lithic technology and evolutionary ecology that has received considerable attention lately involves lithic raw material selection, use, and discard. This is partially due to the fact that lithic raw material source locational studies can provide some reliable measure of the circulation range of tool makers and users. Beck et al. (2002) adopt an optimal foraging model to assess transport and quarry behaviors in the Great Basin. Similar to many of the models noted in the preceding text, they assess efficiency but this time they predict when tools should be made at raw material source locations versus transporting raw material to the residential location for later production into tools. Figure 5. 3 in their study illustrates the point. The *x*-axis to the right represents sequential stages of biface manufacture. The *x*-axis to the left shows travel distance from residence to quarry. A line tangent to the curve predicts the cost-effective travel distance for production of a biface to a particular stage. Ultimately their study shows that distance to lithic raw material sources from residential locations has a significant impact on the extent to which tools are shaped at the source areas.

Other studies have used lithic source locational data to assess travel routes and forager ranges (Daniel 2001; Feblot-Augustins 2009; Jones et al. 2003). Still other studies show that lithic source distances play a role in the extent to which stone tools are reduced, modified, and recycled (Andrefsky 2008; Dibble 1991; Hiscock 2009; Terry et al. 2009). Some archaeologists have explored lithic technological characteristics with models that hold raw material availability and location neutral in an attempt to understand behavioral factors that may influence stone tool production and consumption (Brantingham 2003; Feblot-Augustins 1997). Holding raw material procurement neutral, Brantingham (2006) was able to model forager mobility patterns using a random walk model to separate out information about organizational parameters such as risk sensitivity, time–energy optimization, and levels of planning. Many of the expectations derived from less formal models of forager mobility were consistent with Brantingham's random walk models. "In particular, the Levy mobility model suggests that greater mean and maximum stone transport distances may indeed reflect increases in planning depth, greater optimization of mobility, and greater risk sensitivity" (Brantingham 2006:449).

Beck and Jones (Chapter 5) extend their optimal foraging model to help explain the spread of Paleoindian lithic technology on the North American continent. They suggest that locational factors of high chipping quality lithic raw materials were important for the spread of Clovis blade technology, and to some extent this is evident from tool caches. Their model also suggests that Clovis technology probably originated in the southeastern United States and spread to the north, west, and east from this origin. Of course, this model requires further testing (see Beck and Jones 2010) but it does contradict the assumptions of VanPool et al. (Chapter 4), which adopts the north to south and east migration of Clovis technology through the ice-free corridor of west-central Canada. Beck and Jones further suggest that the Pacific Northwest was originally colonized by aboriginal populations using stemmed points and that Clovis technology came into the interior Pacific Northwest after stemmed point technology was already in place.

Garvey (Chapter 9) also adopts optimality modeling for explanations of lithic raw material procurement. Garvey also acknowledges the less formalized land-use models often associated with lithic technological studies as evolutionary but notes that lithic technological analysis has not been easily translated into fitness measures and she feels it has great promise in pursuing such a path. Garvey's model predicts lithic raw material procurement decisions based on the assumption that lithic raw materials are ranked according to their quality and that high-quality materials improve return rates for stone tool activities. A version of the Bettinger et al. (2006) technological intensification model is adopted (see also Bettinger et al., Chapter 6), with slightly modified parameters. Garvey's model requires procurement and manufacturing costs, measures of raw material quality, rates of return from tools of a given material type, and tool use time. This model is applied to sparse archaeological data from the Middle Holocene of Mendoza, Argentina and has generated a number of testable hypotheses about human land-use practices.

A slightly different approach to optimality models and lithic raw material procurement is presented in Chapter 8 by Ferris. Here lithic raw material proximity is inferred to explain tool production behavior from lithic debitage assemblages. Essentially, lithic raw material provenance is definitively unknown but optimality models indicate that proximity (Beck and Jones, Chapter 5; Beck et al. 2002) and quality (Brantingham et al. 2000; Garvey, Chapter 9) should guide stone tool production decisions. However, Ferris shows that other factors are at play in her study area. Specifically, it is shown that activity type or artifact function may be linked to differences in lithic raw material type preferences. This is similar to results obtained by Braun et al. (2009) that show lithic raw material quality may be defined more broadly than simply "chipping quality" and may extend to other characteristics of the raw material such as durability for performance of certain tasks and edge sharpness for specific functions. This suggests that models need to be crafted with these contexts in mind. Raw material quality may be gauged by homogeneity of structure and brittleness in some situations but other situations may link raw material quality with durability or shape.

Lithic raw material provenance has great potential to generate extremely reliable information about aboriginal land-use practices and/or aboriginal exchange networks because locationally diagnostic sources of stone can be mapped against tool use and depositional locations. Unfortunately, most toolstone found on archaeological sites worldwide is composed of cryptocrystalline silicates such as chert and flint. Unlike obsidian and other fast cooling igneous rocks (Eerkens et al. 2007; Shackley 2005), chert has been difficult to assess for provenance macroscopically or geochemically. In their study of Scandinavian chert Hogberg and Olausson (2007) attempted to characterize cherts by macroscopic characteristics such as color, structure, translucency, and cortex condition. They also attempted various geochemical techniques to establish chert provenance. Unfortunately, they found as much within-source heterogeneity as between-source homogeneity with regard to chert characteristics. They discovered that Scandinavian chert has the same kinds of problems with diagnostic provenance as most other cherts in all parts of the world – it is impossible to determine small-scale locational differences. Unfortunately, archaeologists conducting technological studies and those applying evolutionary models to chert locations have generally ignored this situation and have assumed provenance of cherts by some unknown or unexplained reasons. We feel this can create significant interpretive problems and we believe that there are new techniques and data showing that not all cherts are immune to diagnostic provenance studies. Some progress is being made in the area of authigenic biogenic mineral formation analysis in cherts that is promising for provenance (Foradas 2003; Hughes et al. 2010). There have also been some luminescence analysis of cherts, particularly fluorescence emission analysis, that is effective for chert provenance (Akridge and Benoit 2001; Lyons et al. 2003). There is also evidence that not all chert and flint were formed under deep-sea submarine contexts and that some cherts may have formed in sedimentary contexts associated with fissure eruptions of lava or volcanic venting, creating diagnostic trace elements for very restricted ranges of chert outcrops (Andrefsky et al. 2010; Orr et al. 1999). We feel it is time for lithic researchers to embrace the lithic raw material provenance challenge in both informal models and formal models of evolutionary ecology.

Another characteristic of evolutionary ecology and particularly optimal foraging models is an underlying assumption that optimal food gathering strategies or foraging efficiency or production strategies is a proxy for fitness. In other words, the most optimal production or subsistence strategies correlate with the most fit individuals. Stated another way, optimal foraging theory, "…presumably implies that the variables analyzed in place of fitness – for example, foraging efficiency and caloric intake – vary predictably with fitness and might even imply that this can be, or has been documented empirically" (Bamforth 2002:439). Unfortunately, this has not been demonstrated. We have no evidence that actually demonstrates efficient food collection and consumption strategies with greater fitness. Similarly, there is substantial evidence that problems associated with adaptive strategies typically have many local optima (Bettinger et al. 1996:149). As such, if there is more than one local optimum, populations may reach and maintain those different optimal solutions depending on where their starting points are with regard to a particular problem. This suggests that optimal solutions are multiple and depend on the context of the situation. Looking at this from a more contemporary example may reveal how complicated this situation can be. When duck hunting, it may be most effective to shoot tungsten-loaded shot, because it has a higher density than lead or steel, and as such, it carries farther down range and impacts targets with more energy. However, it may not be the most optimum shot because it is not easy to find in stores, it is more expensive than alternates, and it is too dense to use in many older make shotguns. Loads made with steel shot might be more optimal because they are more readily available, less expensive, and easily shared among hunters in the field – even if they are not the most effective for bringing home ducks. It is important to remember that there may be multiple local optima when modeling complicated data sets such as stone tools. Again, context of study can play an important role in understanding the relevance of model parameters.

Chapter 11 by Quinn could be discussed in several sections of this overview focused on costly signaling theory and its role in lithic technological systems. His chapter takes on issues related to both cultural transmission and models of optimality. Quinn's contribution highlights the need for methodologically sound models to incorporate new theoretical toolkits to interpret lithic technological systems. We chose to end the HBE section with this chapter because we feel that costly signaling theory rightly belongs within the larger theory of HBE. Costly signaling approaches are common in anthropological studies dealing with subsistence data such as meat procurement and sharing (Bliege Bird and Smith 2005; Hawks and Bliege Bird 2002). Fewer studies have focused on archaeological studies and fewer yet have focused on lithic technology and costly signaling theory (McGuire and Hildebrandt 2005; Mithen 2008). Quinn's chapter adds to that small but growing assemblage of archaeological studies dealing with costly signaling theory.

LITHIC TECHNOLOGY, NEUTRAL VARIABLES, AND CULTURAL TRANSMISSION

When Dunnell (1978) theoretically separated style from function in archaeological materials and Meltzer (1981) applied it to a class of stone tools they equated these traits as selectively neutral and selected upon, respectively. Meltzer's study concluded that scrapers had functional characteristics and were selected upon. It was Neiman's studies of architecture and ceramics (1990, 1995) that operationalized stylistic variation in an evolutionary context. Through a series of mathematical models he showed that stylistic variation (exterior lip decoration on Woodland cooking pots) was selectively neutral and that variation within this class of decoration was introduced as a result of drift and/or cultural transmission in the Boyd and Richarson (1985) and Cavalli-Sforza and Feldman (1981) evolutionary genre. He emphasized that the Markovian structure of drift makes it likely that isolated groups will tend to diverge from one another when considering stylistic traits and that under these circumstances only some form of cultural transmission among groups shall increase similarity of stylistic characters (Neiman 1995:31). His work with cultural transmission and ceramics was corroborated by others investigating aspects of neutral evolution and drift in ceramics (Lipo et al. 1997; Shennan and Wilkinson 2001). It was not long before cultural transmission studies were directly applied to lithic technological assemblages (Bettinger and Eerkens 1997, 1999). Aspects of cultural transmission theory such as the origins of material variation and influences of copying error were explored with stone tool examples (Buchanan and Hamilton 2009; Eerkens 2000; Eerkens and Lipo 2005, 2007; Hamilton and Buchanan 2009).

In our opinion one of the classic studies of cultural transmission using stone tool technology was the investigation of the spread of the bow and arrow in the Great Basin (Bettinger and Eerkens 1997, 1999; Eerkens et al. 2006). Here they explore possible explanations as to why some Elko points from Nevada some Rosegate points from California are misclassified. After controlling for age, a series of metric attributes from the two point types from each of the two regions were investigated. Their analysis shows that misclassified Elko points from Nevada may be attributed to multifunctional properties of darts. These are believed to have been used as projectiles and as cutting tools that required resharpening. However, misclassification of Rosegate points from California (based on base width measurements) cannot be attributed to resharpening and instead was the result of differences in cultural transmission and regional adoption of the bow and arrow. They demonstrate that adoption of the bow and arrow in central Nevada was probably a result of indirect bias transmission where point makers acquired multiple aspects of this technology as a complete package. The adoption of the bow and arrow in eastern California, however, was probably a result of guided variation where there was a great deal of experimentation resulting in more variation in Rosegate point characteristics (Bettinger and Eerkens 1999:236–237).

Two chapters in the volume utilize novel measurement techniques to examine evolutionary patterns. Lipo et al. (Chapter 12) and Goodale et al. (Chapter 13) both examine attributes associated with the haft element or base of particular types of stone tools. Lipo et al. use the results to produce a seriation and then discuss cultural inheritance in terms of geographic proximity.

Goodale et al. (Chapter 13) extends lithic technological organization by examining projectile points in Southwest Asia and experimentally manufactured points produced by Ishi, a member of the Yahi/Yana indigenous peoples of north central California. They develop a technique to characterize projectile point notching styles and use clustering techniques to isolate small groups of similar specimens (presumably made by individual artisans). They argue that the high morphological variation across the early Neolithic landscape may signal that the el-Khiam point was invented and spread through informal information exchange without specific student to teacher learning. Their chapter also emphasizes the importance of considering the measurements analysts take on stone tools. Their argument stems from realizing which attributes reflect original production and which reflect tool life history; the former rather than the later are representative of evolutionary patterns concerning information exchange and how to produce material culture.

Another chapter (Stevens, Chapter 14) dealing with cultural transmission theory attempts to combine aspects of HBE with dual inheritance theory (DIT) or cultural transmission, to investigate stone tool technology. This chapter credits Julian Steward's brand of cultural ecology as the middle ground between HBE and DIT. It uses the shift in relative proportions of multifunctional tools to specialized tools over the past 10,000 years in California to demonstrate how the blended model can work. Stevens suggests that HBE explains how subsistence changes appear while DIT provides a plausible evolutionary mechanism for culture change given rules on how information is transmitted. He says, "HBE highlights the economic factors conditioning technological change while DIT helps explain why technological changes might spread even if specific groups are resistant." The interesting point of the chapter is that emphasis is put on local contexts for any study (similar to what Steward would emphasize). "This suggests that any attempt to model individual decision making should consider the context of the task, the available technology, and work organization." We too feel these are important factors in any evolutionary modeling program or lithic technology study and are too often overlooked either by generalized models or detailed data analysis, respectively.

The Prentiss et al. chapter (this volume) does not use formal modeling and might be considered a detailed contextual study of the slate tool industry at one site. The chapter discusses and attempts to explain the evolution of the slate tool industry in a complex hunting and gathering economy. They show that slate technology can be viewed at multiple scales of artifact evolution (micro and macro). They also show that at the micro evolutionary scale slate tools appear to have a general trend toward increased production levels over time, suggesting a process of selection for the tool. At the same time, overall, there is no indication of increased stylistic diversity or adoption of more slate tools with higher levels of production effort in general at the site. However, they demonstrate that more affluent households tended to have higher frequencies of the more costly produced tools and the same households showed a greater frequency of stylistic variability in slate tools. The authors suggest that the slate tool industry at the Bridge River Site shows evolutionary change at multiple scales indicating that group selection may be at play. They note, "*Membership in groups with integrated socioeconomic and political strategies and with-group dominated transmission systems may have offered stronger impacts on fitness than idiosyncratic tactics associated with (and artifacts used by ...) individuals.*" Anti-conformist transmission is suggested as a cause of differential stylistic markers for particular households. We believe this chapter covers a great deal of ground from different scales of evolution to group selection to models of neutrality related to stylistic differences. It too emphasizes context of study within an evolutionary perspective.

We have included the VanPool et al. chapter (Chapter 4) within the discussion associated with cultural transmission. But it could very well be included within the section on culture history, where we discuss selectionist approaches to evolutionary process. However, the emphasis of the culture historical section is with stone tools and phylogenetic analysis. We feel the VanPool et al. chapter emphasizes aspects of transmission associated with stimulated variation and reduced variation in populations even if much of the discussion and diagrams relate to natural selection. This chapter clearly cross-cuts both evolutionary approaches in the way Chapter 14 by Stevens attempts to link HBE and DIT. They used metric data from Paleoindian period sites from across the Southwest and also examined single-site metric data from Blackwater Draw in New Mexico. Both data sets show a bulge or increased variation during the Late Paleoindian period with regard to projectile point attributes. This pattern coincides nicely with the evolutionary notions of innovation (increased variations) in times of stress followed by selective forces to decrease variation.

We believe Chapter 4 by VanPool et al. is another example of common ground gathering under the larger Darwinian umbrella, particularly in the area of lithic technological studies. We interpret this chapter as one that emphasizes human choice and ingenuity to stimulate variation in technology when needed. They show stimulated variation is associated with climatic stress, changes in residential sedentism, and other shifts. Those shifts are reflected as human innovations and choices in technological variations, whether they be horizontal via new group interactions or from other sources. The authors note, "Inventions … can result from transmission errors, novel combinations of previously existing variants, intentional efforts to improve the efficiency of some technology, and a host of other factors." Perhaps a decade ago some of the authors of this chapter would not have made such statements, instead preferring to focus on the more concrete details of analyzing the historical patterns of differential trait representation in the archaeological record. In any event, this chapter shows concrete steps toward integrating Darwinian selection with aspects of cultural transmission using stone tool data and we think it goes a long way toward solidifying lithic technological analysis within an evolutionary framework.

SUMMARY

We have chosen to use the term *lithic technological system* throughout this volume because we believe that it can be easily defined as a concept in which stone and stone tools are under the adaptive umbrella that influences fitness and reproductive success in individuals who use stone to make a living. As we believe readers of this volume will come to realize, there is great potential for interpreting stone tool assemblages that also extends to providing a theoretical perspective that allows us to deal with time depth in the archaeological record that other subfields of anthropology are able to avoid (Shott, Chapter 3).

This volume stems from both the recent use of evolutionary theory in lithic studies but also from the lack of theory generally used in lithic studies. Historically, lithic studies have been focused on method building and analytical means partially because of access to ever advancing technology. One very apparent example is the use and application of portable X-ray fluorescence technology (pXRF) in sourcing studies which has allowed the attainment of elemental chemistry much more efficiently. The important link here is that data gained from pXRF or XRF technology in general are well suited to applying concepts from behavioral ecology such as optimality models. This is not to say this technology is without fault, because there are still challenges on the horizon for integrating this and other technologies into lithic studies (Goodale et al. 2011; Shackley 2010).

Recently there have been great advances toward understanding concepts such as curation (e.g., Andrefsky 2008 and references therein) and its usefulness as a conceptual tool in lithic studies. In this volume we have tried to bring together authors with specialties that can aid us in both using these recent conceptual ideas such as artifact life-history and use them to move to the theoretical level and apply concepts from evolution to understanding lithic technological systems. This volume represents a culmination of those efforts. We think this collection goes a long way toward merging evolutionary theory with the interpretation of lithic technological systems.

REFERENCES

Abbott, Alysia, L., Robert D. Leonard, and George T. Jones. 1996. Explaining the Change from Biface to Flake Technology: A Selectionist Application, in *Darwinian Archaeologies*, edited by Herbert D. G. Maschner, pp. 33–42, Plenum Press, New York.

Ahler, Stanley, and Phil R. Geib. 2000. Why Flute? Folsom Point Design and Adaptation. *Journal of Archaeological Science* 27:799–820.

Akridge, D. Glen, and Paul H. Benoit. 2001. Luminescence Properties of Chert and Some Archaeological Applications. *Journal of Archaeological Science* 28:143–151.

Andrefsky William, Jr. 1994. The Geological Occurrence of Lithic Material and Stone Tool Production Strategies. *Geoarchaeology: An International Journal* 9:345–362.

Andrefsky William, Jr. 2006. Experimental and Archaeological Verification of an Index of Retouch for Hafted Bifaces. *American Antiquity* 71:743–759.

Andrefsky William, Jr. 2008. Projectile Point Provisioning Strategies and Human Land-Use. In *Lithic Technology: Measures of Production, Use and Curation*, edited by William Andrefsky, Jr., pp. 195–214. Cambridge University Press, Cambridge.

Andrefsky, William, Jr., Jennifer M. Ferris, Justin P. Williams, Nathan B. Goodale, and George T. Jones. 2010. Geologic Contexts and Diagnostic Provenance of Cherts, Paper presented at the 2010 Annual Meeting of the Society for American Archaeology, St. Louis, MO.

Bamforth, Douglas B. 1986. Technological Efficiency and Tool Curation. *American Antiquity* 51:38–50.

Bamforth, Douglas B. 2002. Evidence and Metaphor in Evolutionary Archaeology. *American Antiquity* 435–452.

Bamforth, Douglas B., and Mark S. Becker. 2000. Core/Biface Ratios, Mobility, Refitting, and Artifact Use-Lives: A Paleoindian Example. *Plains Anthropologist* 45:273–290.

Beck, Charlotte. 1995. Functional Attributes and the Differential Persistence of Great Basin Dart Forms. *Journal of California and Great Basin Anthropology* 17:222–243.

Beck, Charlotte, and George T. Jones. 2010. Clovis and Western Stemmed: Population Migration and the Meeting of the Two Technologies in the Intermountain West. *American Antiquity* 75:81–116.

Beck, Charlotte, Amanda K. Taylor, George T. Jones, Cynthia M. Fadem, Caitlyn R. Cook, and Sara A. Millward. 2002. Rocks Are Heavy: Transport Costs and Paleoarchaic Quarry Behavior in the Great Basin. *Journal of Anthropological Archaeology* 21:481–507.

Bement, Leland. 2002. Pickin' Up the Pieces: Folsom Projectile Point Resharpening Technology. In *Folsom Technology and Lifeways*, edited by J. E. Clark and M. B. Collins, pp. 135–140, Lithic Technology Special Publication No. 4.

Bettinger, Robert L., Robert Boyd, and Peter J. Richardson. 1996. Style, Function, and Cultural Evolutionary Process. In *Darwinian Archaeologies*, edited by Herbert D. G. Maschner, pp. 133–164, Plenum Press, New York.

Bettinger, Robert L., and Eerkens, Jelmer W. 1997. Evolutionary Implications of Metrical Variation in Great Basin Projectile Points. In *Rediscovering Darwin*, edited by C. M. Barton and G. Clark, pp. 177–191. Archaeological Papers of the American Anthropological Association No. 7, Arlington, VA.

Bettinger, Robert L., and Eerkens, Jelmer 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, Robert L., Bruce Winterhalder, and Richard McElreath. 2006. A Simple Model of Technological Intensification. *Journal of Archaeological Science* 33:538–545.

Bleed, Peter. 1986. The Optimal Design of Hunting Weapons: Maintainability or Reliability. *American Antiquity* 51:737–747.

Bliege Bird, Rebecca, and Eric Alden Smith. 2005. Signaling Theory, Strategic Interaction and Symbolic Capital. *Current Anthropology* 46(2):221–248.

Boone, James L. 1992. Conflict, Competition, and the Emergence of Hierarchies. In *Evolutionary Ecology and Human Behavior*, edited by Eric Alden Smith and Bruce Winterhalder, Aldine Transaction, New Brunswick, NJ.

Boone, James L., and Eric Alden Smith. 1998. Is It Evolution Yet? A Critique of Evolutionary Archaeology. *Current Anthropology* 39(Supp):141–173.

Bousman, C. Britt. 2005. Coping with Risk: Later Stone Age Technological Strategies at Blydefontein Rock Shelter, South Africa. *Journal of Anthropological Archaeology* 24:193–226.

Boyd, Robert, and Peter J. Richarson. 1985. *Culture and the Evolutionary Process*. University of Chicago Press, Chicago.

Boyd, Robert, and Peter J. Richarson. 1992. How Microevolutionary Processes Give Rise to History. In *History and Evolution*, edited by M. H. Nitecki and D. V. Nitecki, pp. 179–209, SUNY Press, Albany.

Brantingham, P. Jeffrey. 2003. A Neutral Model of Stone Raw Material Procurement. *American Antiquity* 68:487–509.

Brantingham, P. Jeffrey. 2006. Measuring Forager Mobility. *Current Anthropology* 47:435–459.

Brantingham, P. Jeffrey, John W. Olsen, Jason A. Rech, and Andrei I. Krivoshapkin. 2000. Raw Material Quality and Prepared Core Technologies in Northeastern Asia. *Journal of Archaeological Science* 27:255–271.

Braun, David R., Thomas Plummer, Joseph V. Ferraro, Peter Ditchfield, and Laura C. Bishop. 2009. Raw Material Quality and Oldowan Hominin Toolstone Preferences: Evidence from Kanjera South Kenya. *Journal of Archaeological Science* 36:1605–1614.

Buchanan, Briggs, and Mark Collard. 2007. Investigating the Peopling of North America through Cladistic Analysis of Early Paleoindian Projectile Points. *Journal of Anthropological Archaeology* 26:366–393.

Buchanan, Briggs, and Mark Collard. 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, Briggs, and Marcus J. Hamilton. 2009. A Formal Test of the Origin of Variation in North American Early Paleoindian Projectile Points. *American Antiquity* 74:279–298.

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

Charnov, Eric L. 1976. Optimal Foraging: The Marginal Value Theorem. *Theoretical Population Biology* 9:129–136.

Clarkson, Chris. 2002. An Index of Invasiveness for the Measurement of Unifacial and Bifacial Retouch: A Theoretical, Experimental and Archaeological Verification. *Journal of Archaeological Science* 29:65–75.

Clarkson, Chris. 2008. Changing Reduction Intensity, Settlement and Subsistence in Wardaman Country, Northern Australia. In *Lithic Technologies: Life-Cycles of Production and Retouch*, edited by William Andrefsky, Jr., pp. 286–316, Cambridge University Press, Cambridge.

Daniel, I. Randolf, Jr. 2001. Stone Raw Material Availability and Early Archaic Settlement in the Southeastern United States. *American Antiquity* 66:237–266.

Darwent, John, and Michael J. O'Brien. 2006. Using Cladistics to Construct 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 Transaction, New Brunswick, NJ.

Dibble, Harold L. 1991. Local Raw Material Exploitation and Its Effects on Lower and Middle Paleolithic Assemblage Variability. In *Raw Material Economies among Prehistoric Hunter-Gatherers*. edited by A. Montet-White and S. Holen, pp. 33–48. University of Kansas Publications in Anthropology, 19, Lawrence, KS.

Dunnell, Robert C. 1978. Style and Function: A Fundamental Dichotomy. *American Antiquity* 43:192–202.

Dunnell, Robert C. 1980. Evolutionary Theory and Archaeology. *Advances in Archaeological Method and Theory* 3:35–99.

Dunnell, Robert C. 1982. Science, Social Science, and Common Sense: The Agonizing Dilemma of Modern Archaeology. *Journal of Anthropological Research* 38:1–25.

Eerkens, Jelmer 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, Jelmer W., Robert L. Bettinger, and Richard McElreath. 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, S. J. Shennan, and M. Collard, pp. 169–183, Aldine Transaction, New Brunswick, NJ.

Eerkens, Jelmer W., Jeffery R. Ferguson, Michael D. Glascock, Craig E. Skinner, and Sharon A. Waechter. 2007. Reduction Strategies and Geochemical Characterization of Lithic Assemblages: A Comparison of Three Case Studies from Western North America. *American Antiquity* 72:585–597.

Eerkens, Jelmer W., and Carl P. Lipo. 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, Jelmer W., and Carl P. Lipo. 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.

Feblot-Augustins, Jehanne. 1997. Middle and Upper Paleolithic Raw Material Transfers in

Western and Central Europe: Assessing the Pace of Change. *Journal of Middle Atlantic Archaeology* 13:57–90.

Feblot-Augustins, Jehanne. 2009. Revisiting European Upper Paleolithic Raw Material Transfers: The Demise of the Cultural Ecological Paradigm? In *Lithic Materials and Paleolithic Societies*, edited by Brian Adams and Brooke Blades, pp. 25–46, Wiley-Blackwell, Oxford.

Fitzhugh, Ben. 2001. Risk and Invention in Human Technological Evolution. *Journal of Anthropological Archaeology* 20:125–167.

Foley, Robert. 1987. Hominid Species and Stone Tool Assemblages: How Are They Related? *Antiquity* 61:380–392.

Foley, Robert, and Marta M. Lahr. 2003. On Stony Ground: Lithic Technology, Human Evolution, and the Emergency of Culture. *Evolutionary Anthropology* 12:109–122.

Foradas, James G. 2003. Chemical Sourcing of Hopewell Bladelets: Implications for Building a Chert Database for Ohio. In *Written in Stone: The Multiple Dimensions of Lithic Analysis*, edited by P. Nick Kardulias and Richard W. Yerkes, pp. 87–112, Lexington Books, Lanham, MD.

Gabora, Liane. 2006. The Fate of Evolutionary Archaeology: Survival or Extinction? *World Archaeology* 38:690–696.

Goodale, Nathan, David G. Bailey, George T. Jones, Catherine Prescott, Elizabeth Scholz, Nicholas Stagliano, and Chelsey Lewis. 2011. pXRF: A Study of Inter-instrument Performance. In press *Journal of Archaeological Science* 39:875–883.

Goodale, Nathan B., Ian Kuijt, Shane MacFarlan, Curtis Osterhoudt, and Bill Finlayson. 2008. Lithic Core Reduction Techniques: A Model for Predicting Expected Diversity. In *Lithic Technology: Measures of Production, Use, and Curation*. edited by William Andrefsky, Jr., pp. 317–336, Cambridge University Press, Cambridge.

Goodale, Nathan, Heather Otis, William Andrefsky Jr., Ian Kuijt, Bill Finlayson, and Ken Bart. 2010. Sickle Blade Life-History and the Transition to Agriculture: An Early Neolithic Case Study from Southwest Asia. *Journal of Archaeological Science* 37:1192–1201.

Goodyear, Albert C. 1974. *The Brand Site: A Techno-Functional Study of a Dalton Site in Northeast Arkansas.* Arkansas Archaeological Survey Publications on Archaeology, Research Series 7.

Hamilton, Marcus, and Briggs Buchanan. 2009. The Accumulation of Stochastic Copying Errors Causes Drift in Culturally Transmitted Technologies: Quantifying Clovis Evolutionary Dynamics. *Journal of Anthropological Archaeology* 28:55–69.

Hawkes, Kristen, and Rebecca Bliege Bird. 2002. Showing Off, Handicap Signaling, and the Evolution of Men's Work. *Evolutionary Anthropology* 11(2):58–67.

Hiscock, Peter. 2009. Reduction, Recycling, and Raw Material Procurement in Western Arnhem Land, Australia. In *Lithic Materials and Paleolithic Societies*, edited by Brian Adams and Brooke Blades, pp. 78–94, Wiley-Blackwell, Oxford.

Hiscock, Peter, and Val Attenbrow. 2003. Early Australian Implement Variation: A Reduction Model. *Journal of Archaeological Science* 30:239–249.

Hiscock, Peter, and Chris Clarkson. 2007. Retouched Notches at Combe Grenal (France) and the Reduction Hypothesis. *American Antiquity* 72:176–190.

Hogberg, Anders, and Deborah Olaussen. 2009. *Scandinavian Flint: An Archaeological Perspective*. Ashus University Press, Denmark.

Hughes, Richard E., Anders Hogberg, and Deborah Olausson. 2010. Sourcing Flint from Sweden and Denmark: A Pilot Study Employing Non-destructive Energy Dispersive X-ray Fluorescence Spectrometry. *Journal of Nordic Archaeological Science* 17:15–25.

Hughes, Susan S. 1998. Getting to the Point: Evolutionary Change in Prehistoric Weaponry. *Journal of Archaeological Method and Theory* 5:345–408.

Jennings, Jesse D. 1968. *Prehistory of North America*. 2nd ed. McGraw-Hill, New York.

Jeske, Robert J. 1989. Economies in Raw Material Use by Prehistoric Hunter-Gatherers. In *Time, Energy, and Stone Tools*, edited by R. Torrence, pp. 34–45, Cambridge University Press, Cambridge.

Jones, George T., Charlotte Beck, Eric E. Jones, and Richard E. Hughes. 2003. Lithic Source Use and Paleoarchaic Foraging Territories in the Great Basin. *American Antiquity* 68:5–38.

Jones, George T., Robert D. Leonard, and Alyssa L. Abbott. 1995. The Structure of Selectionist Explanations in Archaeology. In *Evolutionary Archaeology: Methodological Issues*, edited by P. A. Teltser, pp. 13–32, University of Arizona Press, Tucson.

Kelly, Robert L. 1988. The Three Sides of a Biface. *American Antiquity* 53:717–734.

Kelly, Robert L., and Lawrence C. Todd. 1988. Coming into the Country: Early Paleoindian Hunting and Mobility. *American Antiquity* 53:231–244.

Krieger, Alex D. 1944. The Typological Concept. *American Antiquity* 9:271–288.

Kuhn, Steven L. 2004. Upper Paleolithic Raw Material Economies at Ucagizli Cave, Turkey. *Journal of Anthropological Archaeology* 23:431–448.

Leonard, Robert D., and George T. Jones. 1987. Elements of an Inclusive Evolutionary Model for Archaeology. *Journal of Anthropological Archaeology* 6:199–219.

Lipo, Carl P., M. Madsen, Robert Dunnell, and Terry Hunt. 1997. Population Structure, Cultural Transmission, and Frequency Seriation. *Journal of Anthropological Archaeology* 16:301–333.

Lipo, Carl P., Michael J. O'Brien, Mark Collard, and Stephan J. Shennan. 2006. Cultural Phylogenies and Explanation: Why Historical Methods Matter. 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. 3–18, Aldine Transaction, New Brunswick, NJ.

Lurie, Rochelle. 1989. Lithic Technology and Mobility Strategies: The Koster Site Middle Archaic. In *Time, Energy, and Stone Tools*, edited by R. Torrence, pp. 46–56, Cambridge University Press, Cambridge.

Lyman, R. Lee, and Michael J. O'Brien. 1998. The Goals of Evolutionary Archaeology: History and Explanation. *Current Anthropology* 39:615–662.

Lyman, R. Lee, and Michael J. O'Brien. 2000. Measuring and Explaining Change in Artifact Variation with Clade-Diversity Diagrams. *Journal of Anthropological Archaeology* 19:39–74.

Lyman, R. Lee, Todd L. VanPool, and Michael J. O'Brien. 2008. Variation in North American Dart and Arrow Points When One or Both Are Present. *Journal of Archaeological Science* 35:2805–2812.

Lyman, R. Lee, Todd L. VanPool, and Michael J. O'Brien. 2009. The Diversity of North American Projectile-point Types, Before and After the Bow and Arrow. *Journal of Anthropological Archaeology* 28:1–13.

Lyons, William H., Michael D. Glascock, and Pete Mehringer. 2003. Silica from Sources to Sites: Ultraviolet Fluorescence and Trace Elements Identify Cherts from Lost Dunes, Southeastern Oregon, USA. *Journal of Archaeological Science* 30:1139–1159.

Mayr, Ernst. 1982. *Systematics and the Origin of Species*, Columbia Classics in Evolution Series. Columbia University Press, New York.

McGuire, Kelly R., and William R. Hildebrandt. 2005. Re-Thinking Great Basin Foragers: Prestige Hunting and Costly Signaling during the Middle Archaic Period. *American Antiquity* 70(4):695–712.

Meltzer, David J. 1981. A Study of Style and Function in a Class of Tools. *Journal of Field Archaeology* 8:313–326.

Mesoudi, Alex, and Michael J. O'Brien. 2008. The Cultural Transmission of Great Basin Projectile-Point Technology: An Experimental Simulation. *American Antiquity* 73:3–28.

McKern, William C. 1939. The Midwestern Taxonomic Method as an Aid to Archaeological Culture Study. *American Antiquity* 4:301–313.

Mithen, Steven. 2008. 'Whatever Turns You On': A Response to Anna Machin, 'Why Handaxes Just Aren't That Sexy'. *Antiquity* 82:766–769.

Neiman, Fraser. 1990. *An Evolutionary Approach to Archaeological Inference: Aspects of Architectural in the 17th-Century Chesapeake*. Ph.D. dissertation, Yale University. University Microfilms, Ann Arbor.

Neiman, Fraser. 1995. Stylistic Variation in Evolutionary Perspective: Inferences from Decorative Diversity and Interassemblage

Distance in Illinois Woodland Ceramic Assemblages. *American Antiquity* 60:7–36.

O'Brien, Michael J., ed. 2008. *Cultural Transmission and Archaeology: Issues and Case Studies*. SAA Press, Washington, DC.

O'Brien, Michael J., John Darwent, and R. Lee Lyman. 2001. Cladistics Is Useful for Reconstructing Archaeological Phylogenies: Palaeoindian Points from the Southeastern United States. *Journal of Archaeological Science* 28:1115–1136.

O'Brien, Michael J., and Thomas D. Holland. 1990. Variation, Selection, and the Archaeological Record. *Archaeological Method and Theory* 2:31–79.

O'Brien, Michael J., and Thomas D. Holland. 1992. The Role of Adaptation in Archaeological Explanation. *American Antiquity* 57:3–59.

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

O'Brien, Michael J., and R. Lee Lyman. 2002. Evolutionary Archaeology: Current Status and Future Prospects. *Evolutionary Anthropology* 11:26–36.

O'Brien, Michael J., R. Lee Lyman, and Robert D. Leonard. 1998. Basic Incompatibilities between Evolutionary and Behavioral Archaeology. *American Antiquity* 63:485–498.

O'Brien, Michael J., R. Lee Lyman, and Robert D. Leonard. 2003. What Is Evolution? A Response to Bamforth. *American Antiquity* 68:573–580.

O'Connell, James F. 1995. Ethnoarchaeology Needs a General Theory of Behavior. *Journal of Archaeological Research* 3:205–255.

Orr, Elizabeth L., William N. Orr, and Ewart M. Baldwin. 1999. *Geology of Oregon*. Kendall/Hunt, Dubuque, IA.

Parry, William J., and Robert L. Kelly. 1987. Expedient Core Technology and Sedentism. In *The Organization of Core Technology*, edited by J. K. Johnson and C. A. Morrow, pp. 285–304. Westview Press, Boulder, CO.

Quinn, Colin Patrick, William Andrefsky, Jr. Ian Kuijt, and Bill Finlayson. 2008. Perforation with Stone Tools and Retouch Intensity: A Neolithic Case Study In *Lithic Technology: Measures of Production Use and Curation*, edited by William Andrefsky, Jr., pp. 150–174. Cambridge University Press, Cambridge.

Ramenofsky, Ann F., Fraser Neiman, and Christopher D. Pierce. 2009. Measuring Time, Population, and Residential Mobility from the Surface at San Marcos Pueblo, North Central New Mexico. *American Antiquity* 74:505–530.

Ritchie, William. 1932. *The Lamoka Lake Site*. Researches and Transactions of the New York State Archaeological Association, Vol. 7, No. 4, Rochester.

Sellet, Frederic, James Donohue, and Matthew G. Hill. 2009. The Jim Pitts Site: A Stratified Paleoindian Site in the Black Hills of South Dakota. *American Antiquity* 74:735–758.

Shackley M. Steven. 2010. Is There Reliability and Validity in Portable X-Ray Fluorescence Spectrometry? *SAA Archaeological Record* 10:17–20.

Shackley M. Steven. 2005. *Obsidian: Geology and Archaeology in the North American Southwest*. University of Arizona Press, Tucson.

Shennan, Stephen J. 2002. Population, Culture History and the Dynamics of Culture Change. *Current Anthropology* 41:811–835.

Shennan, Stephen J., and James R. Wilkinson. 2001. Ceramic Style Change and Neutral Evolution: A Case Study from Neolithic Europe. *American Antiquity* 66:577–593.

Shott, Michael J. 1986. Settlement Mobility and Technological Organization: An Ethnographic Examination. *Journal of Anthropological Research* 42:15–51.

Shott, Michael J. 1996. Innovation and Selection in Prehistory: A Case Study from the American Bottom. In *Stone Tools: Theoretical Insights into Human Prehistory*, edited by G. H. Odell, pp. 279–314. Plenum Press, New York.

Shott, Michael J. 2008. Darwinian Evolutionary Theory and Lithic Analysis. In *Cultural Transmission and Archaeology: Issues and Case Studies*, edited by M. J. O'Brien, pp. 146–157, SAA Press, Washington, DC

Shott, Michael J., and Jesse A.M. Ballenger. 2007. Biface Reduction and the Measurement of Dalton Curation: A Southeastern Case Study. *American Antiquity* 72:153–175.

Surovell, Todd A. 2009. *Toward A Behavioral Ecology of Lithic Technology: Cases from Paleoindian Archaeology*, University of Arizona Press, Tucson.

Terry, Karisa, William Andrefsky, Jr., and Mikhail V. Konstantinov. 2009. Raw Material Durability, Function, and Retouch in the Upper Paleolithic of the Transbikal Region. In *Lithic Materials and Paleolithic Societies*, edited by Brian Adams and Brooke Blades, pp. 256–269, Wiley-Blackwell, Oxford.

Tomka, Steve A. 2001. The Effect of Processing Requirements on Reduction Strategies and Tool Form: A New Perspective. In *Lithic Debitage: Context Form Meaning*, edited by William Andrefsky, Jr., pp. 207–225, University of Utah Press, Salt Lake City.

Torrence, Robin. 1983. Time Budgeting and Hunter-Gatherer Technology. In *Hunter-Gatherer Economy in Prehistory*, edited by G. Bailey, pp. 11–22. Cambridge University Press, Cambridge.

Truncer, James J. 1990. Perkiomen Points: A Study in Variability. In *Experiments and Observations on the Terminal Archaic of the Middle Atlantic Region*, edited by Roger W. Moeller, pp. 1–62. Archaeological Services, Bethlehem, CT.

Ugan, Andrew, Jason Bright, and Alan Rogers. 2003. When Is Technology Worth the Trouble? *Journal of Archaeological Science* 30:1315–1329.

Wallace, Ian J., and John J. Shea. 2006. Mobility Patterns and Core Technologies in the Middle Paleolithic of the Levant. *Journal of Archaeological Science* 33:1293–1309.

Winterhalder, Bruce D., and Eric A. Smith. 1992. Evolutionary Ecology and the Social Sciences. In *Evolutionary Ecology and Human Behavior*, edited by E. A. Smith and B. D. Winterhalder, pp. 3–23, Aldine de Gruyter, New York.

Wittohft. John. 1949. An Outline of Pennsylvania Indian History, Pennsylvania History, *Quarterly Journal of Pennsylvania Historical Association*, Vol. 16, No. 3, pp. 3–15, Harrisburg.