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
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 Richardson 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
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 compris-
ing 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 selection-
ist 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 trans-

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 attri-
butes or characters that link the various taxa (Buchanan and Collard 2008).

Foley used cladistics on stone tool assemblages to establish relatedness among
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 descent. 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 phylogenetic 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 phylogenetic 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 Richardson 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 western 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 lithicdebitage 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 tool-stone 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 Richardson (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 and 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.

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