Chapter 4
Natural Selection, Material Culture, and Archaeology

Nathan Goodale

Introduction

A Darwinian approach to evolution is to understand that natural selection is the mechanism that operates to change biological populations over time. Charles Darwin wrote that natural selection is the "preservation of favourable variations, and the rejection of injurious variations" (1859). Darwin also recognized that for natural selection to produce change over time, some variations would be favored over others. Favored variations (or traits) were most likely selected through reproduction that was or was not passed on to future generations. Moving toward the perspective of natural selection in archaeology today, the concept is applied to human behavior and material culture that are the products of that behavior, recognizing that some behaviors may have greater payoffs than others. In other words, behaviors become metaphor for biological traits when acted out in a social setting, and some behaviors will be selected over others because they have an impact on fitness. The purpose of this chapter is to introduce the reader to the concept of natural selection and its implication that when behavior is examined as a trait, we recognize that it may have consequences for reproductive success. We can then set up hypotheses to test in the archaeological record by examining the materials that are the by-product of human behavior.

The Theory of Natural Selection

Within an evolutionary paradigm, natural selection operates on the individual, but the result is encountered at the population level (see Walsh et al., Chap. 2, this volume). Most individual organisms have unique genetics that constitute their genotype. In conjunction with the organisms' environment, their genotype helps to define the phenotype, or the outward expression of that individual. The phenotype is where selection operates, but the genetic code is what is transmitted from parent to offspring. It is important to note that not all genetic code is evident in the phenotype as an outward expression. A phenotypic expression will be present if a dominant trait is inherited from only one parent. However, for there to be a phenotypic expression for a recessive trait, that trait must be inherited from both parents. Thus, if a recessive trait is only inherited from one parent, it will not be

N. Goodale (✉)
Anthropology Department, Hamilton College, Clinton, NY, USA
e-mail: ngoodale@hamilton.edu

A. M. Prentiss (ed.), *Handbook of Evolutionary Research in Archaeology*,
https://doi.org/10.1007/978-3-030-11117-5_4

expressed phenotypically and therefore will not come under selection, regardless if it is advantageous or injurious. In other words, it will not impact the fitness of the individual carrying the recessive trait. The fitness of an individual is predicated by their success in producing offspring that survive to produce offspring themselves. This is often referred to as individual somatic interests (Herzog and Goodale, this volume). The most successful individuals in perusing mates and producing offspring will have the highest fitness. They will also be the most likely individuals to contribute the most genetic information down the generational line. Subsequently, the genetic composition of a population will change from generation to generation, thus representing the evolutionary process.

It is important to understand that even if a phenotype is expressed, only some traits are likely to be under selection. It is possible to distinguish between those that are under selection, deemed functional traits, and those that are not under selection, deemed adaptively neutral. The frequency of a functionally advantageous trait that is under selection will increase steadily in the population to some ceiling, while an adaptively neutral trait will be the subject of random drift from generation to generation. An adaptively neutral trait will eventually become fixed at the ceiling or disappear among the population (O'Brien and Holland 1990; see also Kandler and Crema, this volume; Laue and Wright, this volume). The frequency of neutral traits in a population is due to random drift, whereas the frequency of functional traits is due to natural selection. Context plays an important role in determining if a trait is functional or neutral and a trait that is under selection in one circumstance may be neutral in another.

Endler (1992, p. 221) suggests that there are three conditions that must be at play in order to recognize the action of natural selection:

> ... the population has (*a*) variation among individuals in some attribute or trait (phenotypic variation); (*b*) a consistent relationship between that trait and mating ability, fertilizing ability, fertility, fecundity, and/or survivorship (fitness variation); and (*c*) a consistent relationship, for that trait, between parents and their offspring, which is at least partially independent of common environment effects (inheritance).

Fitness variation *b* is the important variable to understand among the three. Drift is recognized when the conditions *a* and *c* are met while *b* is not.

This is best understood with a well-known example. Male peacocks are an interesting case because the selective advantage for males to bear long trains is not immediately obvious. The trains are not light and can have variable ornamental size/condition that makes male peacocks more likely to suffer from predation than their female counterparts. The trains are expensive metabolically to produce, and not all male peacocks are able to provide the energy investment toward the growth and maintenance of their train. Therefore, Endler's condition *a* is met with phenotypic variation in peacock trains. Hale et al. (2009) demonstrate that male peacocks with well-endowed trains tend to get more mates than those with more modest trains. Males with trains that were longer and more ornamental also tended to produce more fit offspring (Hale et al. 2009) satisfying Endler's condition *b* where the condition of the train influences mating ability and signals survivorship. Offspring genetically inherit the ability to grow a train, and it is a signal of inheritance, satisfying Endler's condition *c*. We can then conclude that natural selection has shaped this relationship. The peacock train is, by definition, a functional adaptation shaped by natural selection that impacts male fitness. If by chance, Endler's condition *b* was not a factor, and male peacocks with trains that were shorter and less ornamental found mates in the same frequency and fitness levels as those with longer and more ornamental trains, then the male peacock train would be subject to drift, not natural selection.

Natural Selection and Studies of Evolution in Archaeology

Although natural selection and the relationship to biological features are well understood, its influence on human behavior is highly debated. The discussion concerns genetics, and the link to human behavior has been rigorously debated for a half century. While the level of genetic contribution to

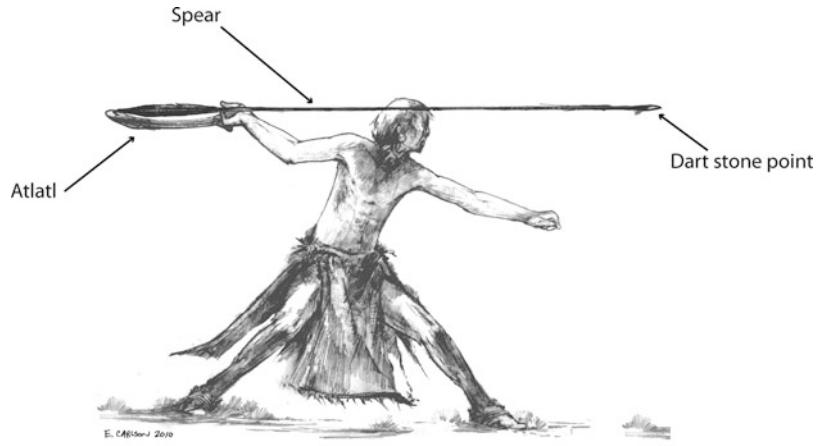

Fig. 4.1 An atlatl and components of the technology. Credit Eric S. Carlson

human behavior is debated, for example, nature vs. nurture, what is clearly evident is that behavior is part of the human phenotype and thus susceptible to natural selection because behavior can have fitness consequences. In the 1970s, archaeologists initiated the argument that human behavior is subject to natural selection and also the products of that behavior including material culture (e.g., Dunnell 1978a, b). The argument suggested that technology contributes to our fitness, and therefore, natural selection relates to the material products of behavior as part of the human phenotype (Leonard and Jones 1987). The link here is that since natural selection acts on phenotypes and phenotypes have fitness consequences, then by definition natural selection acts on material culture as well.

Endler's (1992) argument concerning natural selection in a biological system may be restated for material culture to include (1) variation exists in human-produced technology, (2) that certain variants of technology or components of technology impact fitness, and (3) inheritance occurs through information exchange as information is passed between teachers and pupils. In light of considerations regarding peacock trains, we can also consider Endler's (1992) argument in more detail using an archaeological example of the transition from the atlatl and dart technology to the bow and arrow among North American hunter-gatherers.

Archaeological evidence suggests that before approximately 9000 years ago, the hand-propelled spear or javelin was replaced by the spear-thrower, called an atlatl (e.g., Hughes 1998). The atlatl extends the arm and can substantially expand the range by which a spear can be used (Fig. 4.1). Atlatl technology is comprised of three components including (1) the atlatl, (2) the dart (a long wood spear), and (3) the dart point (typically a stone projectile tip). Over the more than 7000 years during which this technology was in use, the morphologies of these components varied across geographic regions. At approximately 2000 years ago, the bow and arrow was invented and replaced the atlatl and dart throughout much of North America. This replacement was relatively rapid likely representing that this new technology offered considerable advantage to hunters and thus increased fitness. How does Endler's (1992) model fit with the transition from dart to arrow? Understanding phenotypic variation and impacts to fitness is a useful starting point.

For natural selection to affect the evolution of a technological system, there must be variation in the technology that can complete the same task, and some variants may be more efficient at accomplishing the same task than others. Variation may exist within or between technologies, and this can include morphological (size, shape) or raw material variants and/or different combinations of all of those variants for composite technologies.

Atlatls come in multiple forms, for example, some are single units, and others are composite in construction. Some designs make use of weights, often called banner stones, some have formal grips,

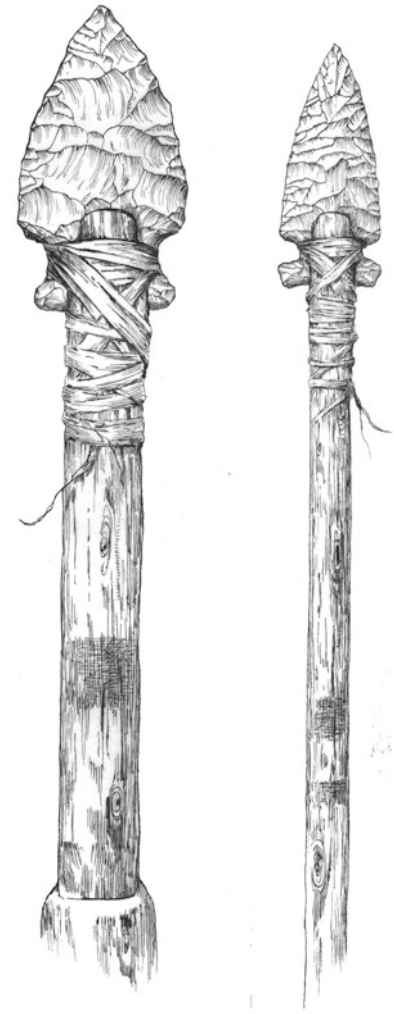

Fig. 4.2 Distinction in morphology of Besant dart technology (left) and Avonlea arrow technology (right). Credit Eric S. Carlson

and raw materials can be highly diverse. The associated dart points also vary substantially given the different approaches to the use of raw material and preferences for form and size.

Natural selection can be said to be acting if any of these variants increase the fitness of the producer/consumer.

The variation between the atlatl/dart and bow and arrow technologies is a difference in propulsive force and accuracy. Natural selection here is potentially operating on both the totality of components comprising each technology and, within each technology, on variations within individual components over time. Natural selection likely operated on variation within the components of the bow and arrow and changes in that technology after it was introduced on the bow size and form, arrow shaft form, and point size and form (e.g., Fig. 4.2). The bow and arrow carried an advantage over the atlatl and dart and undoubtedly led to increased fitness of the producer/consumer, and just as likely more successful variants would refine the technology and be adopted over time.

Archaeologists argue that just like biological traits, cultural traits can also be functional or neutral. Neutral traits are designated as stylistic, and their role is context-specific at any given time (Dunnell 1978a, b; Kandler and Crema, this volume; Laue and Wright, this volume). On the other hand, just as in biology, functional traits do not always enhance fitness. In this case, some traits may be transmitted

via teacher-student learning along generational lines because they are attached to other traits under selection. Endler's argument only requires that some variants affect fitness and the two propulsion technologies largely represent functional traits. However, there are decorative traits in the individual components of each that could be considered stylistic. It could be argued that some functional traits of these technologies do impact fitness where natural selection could be operating to positively or negatively reproduce those traits. This could include optimal projectile point size, bow or string material, or arrow composition, anything that could optimize hunting. This also assumes that hunting in the given population is an activity that, if successful, increases an individual reproductive success.

It is also worthwhile to examine the fitness advantages that the bow and arrow may have for the producer/consumer over the atlatl and dart. The bow and arrow had the same selective advantage over the atlatl/dart that the atlatl/dart had over the javelin. That selective advantage includes increased propulsion distance allowing a hunter to launch a dart from a greater distance from the prey which decreases the likelihood of the prey discovering the hunter and running away. The bow and arrow had the included advantages of greater arrow speed and greater precision and accuracy. The rapid replacement of the atlatl and dart by the bow and arrow across a large part of the North American continent was likely due to natural selection operating on technological decision-making through increasing a hunter's efficiency. At the same time, this assumes that hunting was an activity that, if successful, increased a hunter reproductive success.

Inheritance in technological reproduction is the part of applying natural selection to cultural systems that has been the most contentious and the main reason why it has been used to reject the application of Darwinian principles to explain artifact variation through human behavior. The rationale for the rejection of inheritance in artifact variation is that artifacts do not reproduce like biological organisms. The idea here is that artifacts cannot inherit anything. However, evolutionary archaeologists argue that the teaching-learning process where cultural information is passed between persons is analogous to the biological inheritance process (Boyd and Richerson 1985; Walsh et al., Chap. 2, this volume). While the latter is better understood, archaeologists have argued that the former operates in a similar but less tangible and more complicated way. Where biological transmission occurs from parent to offspring, cultural transmission (or learned behavior) can occur as vertical transmission between parent and offspring, through oblique transmission between learners and relatives or other more experienced members of the social unit, or through horizontal pathways via peer-to-peer transmission. Variation in material culture production can also be a by-product of how much and the mode of instruction given in the teaching-learning process. For example, projectile points may exhibit little variation if there is a positive impact on reproductive success that creates uniform morphologies of the most successful types of points. The mode or intensity of instruction in the cultural transmission process could also relate to the prestige a person may obtain based on some behavioral variant (Quinn, this volume).

The concept of cultural transmission has been used on an intuitive basis in the form of a culture contact and diffusion model where invention of new technologies is more often a result of diffusion rather than independent invention. The concept of cultural transmission was more introduced in the evolutionary anthropology of the 1970s and then formally developed in the 1980s (Boyd and Richerson 1985; Cavalli-Sforza and Feldman 1981; Dunnell 1978a, b). From this perspective, similarity in form, especially for traits that equate to style, normally indicates a degree of contact and transmission. Anthropologists and other behavioral scientists do not have a strong definition for what actually constitutes transmitted cultural information. Simply stated, in cultural transmission, we do not have the exact equivalent to the gene. What makes studying cultural transmission even more complicated is that the packages are stored and reproduced in different ways, often to generate opportunities for the producers/consumers that can impact reproductive success. One approach that archaeologists employ is through morphometric analyses and the notion that artifact physical form and similarities/differences between artifacts convey how closely they are related. Goodale et al. (2015)

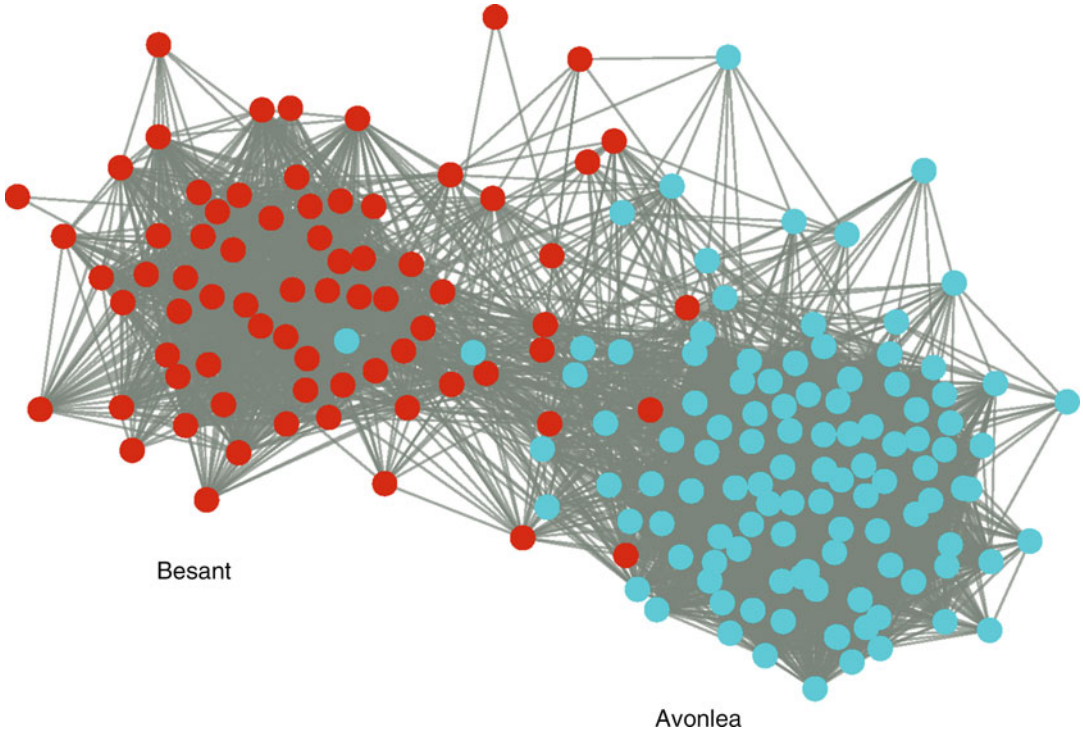

Fig. 4.3 The dart to arrow transition graphed by technology where Besant dart points and Avonlea arrow points

applied this approach to a group of projectile points from the early Neolithic site of Dhra', Jordan. They argue that similarity in artifact form relates to both the form of transmission and the knapping kit used in production.

Goodale et al. (2011) utilize a similar approach for the transition from dart (Besant) to arrow (Avonlea) points in the northern Plains of North America. Using network analysis, they graphically display the relationship of morphology between dart and arrow points (Fig. 4.3). Lines are called degrees that connect nodes which represent the artifacts that are most similar in morphology. It is clear that the network of dart and arrow points is partitioned into two sub-networks, which mostly align with the cultural units, or what archaeologists call *types* previously labeled Besant and Avonlea projectile point traditions. The blue nodes represent Avonlea projectile points, likely used within a bow and arrow technology, while the red nodes represent Besant dart points, likely used within an atlatl composite technology. The results suggest that these dart and arrow points are quite distinct in morphology. There are clearly two sub-networks in this technological system of making stone tips for points that represent a larger network of technological decision-making (Herzog and Goodale, this volume). What is interesting is that the two sub-networks are connected by some of the artifacts used in the analysis. Those artifacts that connect the sub-networks may be experiments or otherwise had traits that natural selection operated on. There are other ways to model the relationships between similar morphologies that suggest a degree of relatedness, for example, cladistics (e.g., O'Brien and Lyman 2001, 2003; Straffon, Chap. 8, this volume). While approaches such as these have provided results, the interesting and potentially problematic aspect to using morphology to talk about relatedness is that in biology, morphology or morphometrics has been completely replaced with the modern mapping of genetics. We still do not have the cultural equivalent of the gene.

When examining the relationship between natural selection and material culture, it is difficult to understand how materiality impacts reproductive success. Material culture such as projectile points

does not genetically reproduce, so the question becomes as follows: Can projectile points have reproductive success? The literal answer is no, but the argument is that artifacts may enhance the reproductive success of their producers/consumers depending on the nature of the enterprise and the performance of the items in question. This implicates the notion of replicative success of cultural materials manufactured by humans or those cultural units that have differential persistence across time and space (Leonard and Jones 1987). Replicative success refers to a circumstance when a social group is given a set of alternative forms some will be chosen to be produced and/or consumed (used) more often than others. Replicative success also means that the most commonly chosen forms will be made known to others in the social unit through cultural transmission at the expense of the forms that have less impact on fitness. Replicative success is a concept that allows us to operationalize natural selection in archaeology by considering frequency of technological items, the degree of technological diversity, and the potential causes of that variation.

In Endler's (1992) model, change in a trait that does not enhance fitness will be due to drift, and change in a trait that does enhance fitness will be due to natural selection. Under these parameters, both functional and stylistic traits can have replicative success where functional traits are under natural selection and stylistic traits are subject to drift (Dunnell 1978b). Often artifacts or the tools people used in the past were likely comprised of both functional and stylistic traits. The problem is in understanding which traits are functional and which are stylistic. Experimental archaeology, where artifacts are reproduced and then used in practice, is a possible way to understand which traits are functional and which are stylistic. An experimental archaeologist could replicate projectile points with the same morphology as dart and arrow points. Then they could be hafted and then tested for their relative performance and success rates. To take another technological example, pottery vessels could be replicated and performance tested. The issue with experimental archaeology is that we may garner information about a technology's performance, but we will, however, never be able to recreate the social setting of the past and the impact of those artifacts on actual reproductive fitness in those contexts.

In terms of Endler's argument, a functional trait should remain in use until something better comes along. The archaeological record allows us to understand that functional traits can be adopted and used for a long period of time. This is why evolution via natural selection is perhaps one of the most powerful theoretical perspectives for interpreting the archaeological record because it allows for a depth of time to be a significant factor. However, functional traits may come and go over time, as the producers/users' needs change. The stone end scraper is a technology used in many cultural contexts for long periods of time to scrap the membrane from animal hides. Scraping tools first were adopted hundreds of thousands of years ago. Their frequencies have fluctuated through time, which makes their temporal frequency follow a multimodal distribution. In most cases, end scrapers persisted in roughly the same form (a steep edge perpendicular to a flat surface) until the appearance of metal tools. This is a very functional tool, and there is not much about an un-hafted end scraper that could be considered stylistic (but see Arthur 2018). On the other hand, traits that are stylistic tend to have a unimodal temporal frequency through time. After a stylistic trait comes into being, it gains popularity, rises to a peak, then fades, and eventually disappears. In addition, styles rarely return in the same form which provides the basis of seriation chronology building in archaeology. Unimodal distributions of stylistic traits and the fact that they rarely reoccur in exactly the same form make stylistic traits especially useful for chronology building (Goodale et al. 2011).

Generally, functional traits that have an impact on fitness to the producers/users tend to spread rapidly once they are invented or introduced. The bow and arrow was adopted relatively quickly, meaning that it offered significant advantages to its users over the atlatl and dart. From this example, distinguishing between a functional trait and a stylistic trait may seem easy. However, this example was chosen because it is fairly easy to illustrate. As argued by Goodale et al. (2011), many technological histories offer much more complex scenarios in which style and function are less easily separated. Consequently it may be hard to discern which traits affect fitness. Thus multiple lines of evidence are required to tease apart functional and stylistic traits and to explore their relationships in wider archaeological context.

Signaling and Natural Selection

Archaeologists are used to thinking about questions like as follows: Why did one technological trait replace another? In such cases, experimental archaeology can help us understand the answers to that question through performance-based studies. The degree to which one technological trait brought greater efficiency to food procurement could have enhanced the survival of its producers/users. Because of this relationship, one technological trait could have a likely impact on fitness over another technological trait. It is also likely that a combination of traits in the technological system could be under selection such as the physical tools, the technique of the archer, and the knowledge passed on through cultural transmission required to effectively use and reproduce the components of the system. None of this seems too big of an assumption, despite the fact that we probably cannot demonstrate that early adopters of this technology achieved enhanced reproductive success relative to those that may have held on to the alternative technology (e.g., Bamforth 2002). It may also be suspected, but not easily demonstrated, that the speed with which the shift from darts to arrows occurred was accentuated by some additional process, like conformist or prestige-based cultural transmission (added prestige incentive to have replicative success above survival fitness). And yet there are many other changes in material culture for which appeals to improvements in design and increased efficiency do not appear to be satisfactory solutions.

Binford (1962) argued that artifact function is just as much a part of the social and ideological contexts as it is related to a functional performance. Many efforts in archaeology to explain the social and ideological roles of artifacts have drawn largely from an anthropological perspective of function attributable to Emile Durkheim. With this perspective one might ask the question: How is social integration maintained through the social and ideological roles of artifacts? An evolutionary perspective helps to answer this question. Some artifact production systems are extremely time-consuming and also costly in terms of materials. Their manufacture thus may defy practical logic, thus fitting Veblen's (1899) notion of "conspicuous consumption." Such seeming waste may seem irrational if it does not evidently favor fitness. But if we recognize that the peacock's plumage serves to attract more or higher-quality mates, we also recognize that a similar consequence can happen with those who possess more elaborate technology. Neiman (1997) effectively argues this for the case of Mayan stone monuments (Neiman 1997). Groups of artifacts or types illustrate very nicely the temporal patterns of artificial clades, that is, a group of individuals such as organisms or projectile points that are related by descent (Lyman and O'Brien 2000). Sometimes artifact clades can be long-lived, reach high frequencies, and be widely distributed in time and space, while other artifact clades do not persist and disappear relatively quickly. The reasons for this dichotomy can be complex but in some way or another likely link with natural selection and the fitness consequences of the artifact clade. It is also important that natural selection is taken into account with great time depth when considering the impact on fitness that artifacts can have on humans when looking at evolutionary process over long time spans (see Chap. 6).

Even with the interesting phenomenon that technological clades can come and go in popularity through time and space, and those clades can have an impact on individual fitness, there are interesting analogies to the biological world. Connecting back to the peacock's elaborate plumage example, to explain why the male peacock makes such sizeable investments, biologists make arguments that sexual selection and costly signaling can account for peacock fitness, and individual fitness is advertised by the elaborate plumage (Hale et al. 2009). The case could be made that the male peacock uses its plumage to both attract the female and also convey its relative comparison to other male peacocks. If it turns out that the signal is honest and the peacock's plumage does correlate with other reproductively fit characteristics, discerning females that select males with elaborate plumage as mates will in turn have greater reproductive success. Where time becomes important is in the circumstance that the

behavior is passed on generation to generation, and it impacts female peacock mate choice selection reinforcing male's investments in their plumage.

Humans are very sensitive to signals (see Quinn, this volume), and signals shape the way we interact and perceive the world around us. Signals reach us in a multitude of ways from language all the way to all of our senses (aural, visual, tactile, and olfactory). As an extension to this, our behavior is tied to our material culture, and because of that relationship, our phenotype is also enhanced by material culture. We use material signals as references for group membership to denote objects and activities where signals are associated with individuals or social groups that mark them as distinct from other social groups. Material culture allows for considerable occasions to construct signals, some of which might include the quality and quantity of raw materials used in production, the skill of the producer (s), and the relationship to how many producers versus consumers there are in the population (see Herzog and Goodale, this volume). Personal identity or group membership can be directly tied to the variant of choice (such as the type of raw material selected) to the manipulation of traits (specific combination of raw materials) that the producer/consumer makes. The replicative success of an artifact variant will wax and wane through time but is likely to be linked to the signaling of the most successful variants.

Artifact tool production and use is an interesting case study for signal construction. Tool use can appear early in a human life, actual tool production probably much later. Tool use is likely practiced and enhanced by imitation and through play with peers, parents, and other members of the social unit (Fig. 4.4). Signals can reproduce normative cultural content and reinforce affinities between people (promote social solidarity). On the other hand, signals can show the distinctiveness of the producer/user. In other circumstances, signals can convey some measure of the user's dominance or relative prestige over others. Certain individuals may be dominant because they have the family fitness that can use certain material culture because it is expensive (monetarily or, e.g., expensive in terms of the energy needed to procure raw materials). The link here with natural selection is that cultural materials inherently send signals from the producers and users to the rest of the social unit. That signal can be very much like the peacock's plumage with the potential to convey information regarding individual or even family fitness levels. In mate selection, if the signals have an honest and positive correlation to other aspects of reproductive success, material culture can increase individual reproductive success.

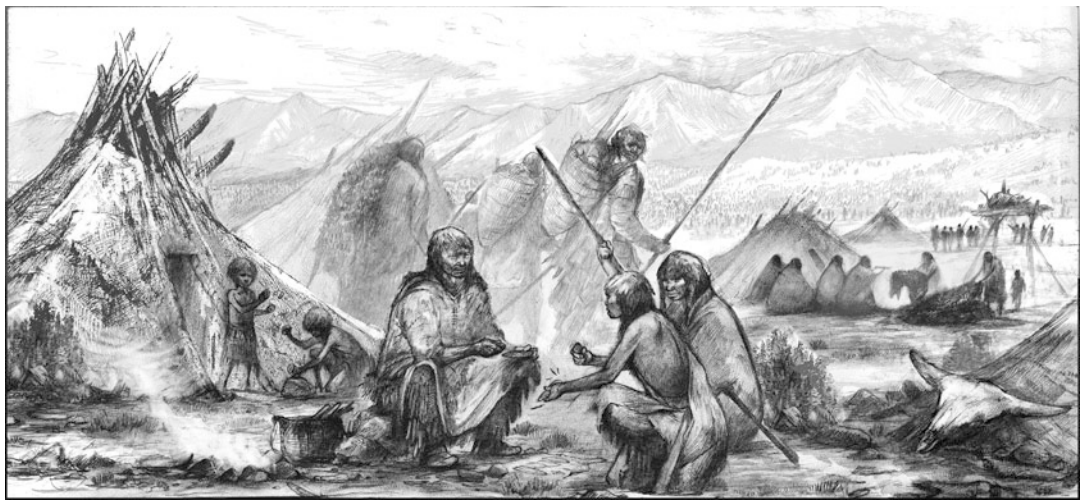

Fig. 4.4 Hunter-gatherer camp with hypothetical situation of children mimicking adult tool use. Credit Eric S. Carlson

Conclusions

This chapter has attempted to provide simple examples of how natural selection operates on biological variation, human behavior, and its by-products especially focused on the production and use of material culture. In making this argument, the emphasis was made that behavioral variation and fitness have a formal relationship. In the recent literature, critiques have been made about the relationship where functional traits are linked to fitness variation (e.g., Bamforth 2002; Eldridge 2009). There is the basic underlying assumption that some technological variants have implications for the reproductive success of their producers/users. There still seems to be an objection to the notion that artifacts have a direct influence on fitness. Perhaps this is because such a relationship fails to account for human agency as part of the process relating tool performance to greater reproductive success? This is not to deny the influence of human agency but instead to make explicit that the variation among artifacts yields differences in efficiencies and that variation influences energy capture and output, two critical variables in maintaining or increasing reproductive success. There is a fundamental relationship between the artifacts and the variable strategies and techniques for using technology. What is complex is the proportion that each contributes to the efficiency of tool production/use. Realizing the relationship between technology and fitness does allow us to construct plausible arguments built on performance studies, considering the modes by which cultural transmission takes place.

Acknowledgments Thanks to Anna Prentiss for the invitation to contribute to this volume. Thank you to George T. Jones and Charlotte Beck who contributed toward this manuscript and to two anonymous reviewers for their comments. Thank you to Eric Carlson who illustrated Figs. 4.1, 4.2, and 4.4. Figure 4.2 is used with permission of Dr. Douglas Macdonald, University of Montana. Thanks also to Lisa Fontes and Brian Connolly for their contribution to the production of Fig. 4.3. Thanks to Alissa Nauman for her support and conversation around this topic.

Data Sharing Statement Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

References

Arthur, K. W. (2018). *The lives of stone tools: Crafting status, skill, and identity of flintknappers*. Tucson, AZ: University of Arizona Press.

Bamforth, D. B. (2002). Evidence and metaphor in evolutionary archaeology. *American Antiquity, 67*, 435–452.

Binford, L. R. (1962). Archaeology as anthropology. *American Antiquity, 28*(2), 217–225.

Boyd, R., & Richerson, P. J. (1985). *Culture and evolutionary process*. Chicago, IL: University of Chicago Press.

Cavalli-Sforza, L. L., & Feldman, M. W. (1981). *Cultural transmission and evolution: A quantitative approach*. Princeton, NJ: Princeton University Press.

Darwin, C. (1859). *On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life*. London: John Murray.

Dunnell, R. C. (1978a). Archaeological potential of anthropological and scientific models of function. In R. C. Dunnell & E. S. Hall (Eds.), *Archaeological essays in honor of Irving B. Rouse* (pp. 41–73). The Hague, The Netherlands: Mouton.

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

Eldridge, N. (2009). Material culture macroevolution. In A. M. Prentiss, I. Kuijt, & J. C. Chatters (Eds.), *Macroevolution in human prehistory: Evolutionary theory and processual archaeology* (pp. 297–316). New York: Springer.

Endler, J. A. (1992). Natural selection: Current uses. In E. F. Keller & E. A. Lloyd (Eds.), *Keywords in evolutionary biology* (pp. 220–224). Cambridge, MA: Harvard University Press.

Goodale, N. B., Jones, G. T., & Beck, C. (2011). Natural selection and material culture. *Evolution: Education and Outreach, 4*, 427–434.

Goodale, N., Andrefsky Jr., W., Osterhoudt, C., Cueni, L., & Kuijt, I. (2015). Cultural transmission and the production of material goods: Evolutionary pattern and measuring morphology. In N. Goodale & W. Andrefsky Jr. (Eds.), *Lithic technological systems and evolutionary theory* (pp. 239–252). Cambridge, UK: Cambridge University Press.

Hale, M. L., Verduijn, M. H., MØller, A. P., Wolff, K., & Petrie, M. (2009). Is the peacock's train an honest signal of genetic quality at the major histocompatibility complex? *Journal of Evolutionary Biology, 22*, 1284–1294.

Hughes, S. S. (1998). Getting the point: Evolutionary change in prehistoric weaponry. *Journal of Archaeological Method and Theory, 5*, 345–408.

Leonard, R. D., & Jones, G. T. (1987). Elements of an inclusive evolutionary model for archaeology. *Journal of Anthropological Archaeology, 6*, 199–219.

O'Brien, M. J., & Holland, T. D. (1990). Variation, selection, and the archaeological record. In M. B. Schiffer (Ed.), *Archaeological method and theory* (Vol. 2, pp. 31–79). Tucson: University of Arizona Press.

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

O'Brien, M. J., & Lyman, R. L. (2003). *Cladistics and archaeology*. Salt Lake City: The University of Utah Press.

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

Neiman, F. D. (1997). Conspicuous consumption as wasteful advertising: A Darwinian perspective on spatial patterns in classic Maya terminal monument dates. In M. Barton & G. A. Clark (Eds.), *Rediscovering Darwin: Evolutionary theory and archaeological explanation* (pp. 267–290). Arlington, VA: American Anthropological Association. Archaeological Papers of the American Anthropological Association No. 7.

Veblen, T. (1899). *The theory of the leisure class*. New York: Macmillan.