Chapter 4

Explaining the Co-occurrence of Traits in the Archaeological Record: A Further Consideration of Replicative Success

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INTRODUCTION

The realization that the archaeological record is typified by the patterned co-occurrence of artifacts or artifact attributes has formed the basis of archaeological research since its inception. These associations have been formally codified in the cultural-historic types that archaeologists rely on. They have formed the basis of the midwestern taxonomic method and the culture areas developed by the cultural historians (e.g., McKern 1939; Willey and Phillips 1958), the “tool kits” and activity assemblages studied by processual archaeologists (e.g., Binford and Binford 1966; Kent 1984), and the social and class structures interpreted by postprocessual and Marxist scholars (e.g., Bawden 1996). Some of the most important and fundamental debates in archaeology, such as the Ford-SpaULDing debate (Ford 1954a, 1954b, 1954c; SpaULDing 1953, 1954a, 1954b), the Binford-Bordes debate (Binford and Binford 1966; Bordes and de Sonneville-Bordes 1970; Dibble 1987; Rolland and Dibble 1990), and the Thomas-Flenniken-Bettiger debate (Bettiger et al. 1991; Flenniken 1985; Flenniken and Raymond 1986; Flenniken and Wilke 1989, 1991; Thomas 1981, 1983), have focused on the meaning and explanation of these associations.

In spite of the analytical importance of the association of traits and the debate that has surrounded it, most archaeologists generally treat these co-occurrences largely as a given, not as something to be explained in and of themselves. The reason for this neglect is probably that these associations can simply be taken for granted when approaching some questions. While the researchers may use the associations either to identify their subject matter (e.g., culture areas) or as a means of gaining information about social structures (e.g., social classes or activity areas), the reason that the traits are associated with one another in the
first place is of only incidental importance. For example, the reason that certain
designs and sand temper co-occur on a particular prehistoric pottery type may
not be important to those who are interested in questions related to temporal
and cultural relationships, social structure, or the specific use of individual
artifacts.

Such associations have profound evolutionary implications, however, and,
therefore, present an interesting and fundamental subject matter for evolutionary
archaeologists. In the same way that biologists are interested in explaining why
particular genetic traits are correlated, evolutionary archaeologists might be
interested in explaining why aboveground dwellings and agricultural production
coccur in a particular area, why a change in grinding technology correlates
with a change in ceramic technology, or why shifts in settlement patterns and
changes in ceramic decoration appear to be associated in a given region. Thus,
instead of being simply a starting point for an evolutionary archaeology, these
associations present important subjects of study.

The foundation for such studies has already been developed within the exist-
ing evolutionary archaeological framework. The basis for an evolutionary ar-
chaeology is the concept of replicative success as presented by Leonard and
Jones (1987). Replicative success is defined as the differential persistence of
traits, whether they are behavioral or material, through time (Leonard and Jones
1987:214). When we are discussing the co-occurrence of artifacts or attributes
of artifacts, we are, in fact, discussing linked replicative success (i.e., the
differential persistence of two or more traits that appear to be connected). Other
evolutionary archaeologists have also proposed that the concept of sorting may
be useful for understanding linked replicative success (Abbott et al. 1996;
McGimsey 1995; O’Brien and Holland 1990; Raphanofsky 1995). However,
these previous discussions have not explored the full range of sorting processes,
nor have they clearly defined sorting.

In this chapter, we suggest that two kinds of processes can lead to linked
replicative success in the archaeological record: hierarchical sorting and sorting
by hitchhiking. We argue that both of these sorting processes may lead to linked
replicative success but that sorting itself is an outcome and should not be
identified as a causal mechanism in evolution. We discuss both of these processes
in turn and provide archaeological examples illustrating their operation.

LINKED REPLICATIVE SUCCESS THROUGH
HIERARCHICAL SORTING

Sorting is a concept that has been used by biologists when discussing evo-
nolutionary hierarchies. It has perhaps been most completely developed by Vrba
sorting as “differential birth and/or death processes among individuals, whether
they be genomic constituents, organisms, populations, or species” (Vrba and
Eldredge 1984:146). It is “a simple description of differential representation; it
contains, in itself, no suggestion about the cause of the sorting” (Vrba and Gould
1986:219). Therefore, sorting is not an outcome. While natural selection may
be the only one (Vrba and Gould 1986:219), it can cause sorting.

While sorting is not a result of natural selection, and the thrust of the present
chapter is that it is not, the hierarchical view of punctuated equilibrium is
an important one for understanding evolutionary processes. Evolutionary processes
can act at different levels, and the scales of genomes, organisms, populations,
and species are the primary levels of study. In this chapter, we discuss how
hierarchical sorting can lead to linked replicative success. Hierarchical sorting
is often used to describe changes at lower levels, but evolutionary processes
can lead to changes at higher levels (McGimsey 1995:256; Vrba and Gould 1986:219).
In hierarchical sorting, natural selection (i.e., punishment or reward) operates on
organisms and gene frequencies at lower levels (Vrba and Eldredge 1984:146).

The ultimate importanta
cation that the proximate
The reason that certain pottery types might be related to temporal use of individual artifacts, however, and, after all, evolutionary processes in explaining why archeologists might be interested in production goals or attributes of certain artifacts (i.e., the function of the artifact) or other characteristics (e.g., the overflow connection). Other processes of sorting may also be connected (Abbott et al. 1996: 3; 1995). However, sorting processes, as can lead to linked sorting and sorting processes may be linked, and should not be identified with the processes of their operation.

When discussing evolutionary changes in species, whether species' or individual representation; it contains, in itself, no statement about causes" (Vrba and Gould 1986:217). Therefore, sorting is not an evolutionary mechanism or force but is instead an outcome. While natural selection is one source of sorting, it is definitely not the only one (Vrba and Gould 1986: 3); drift, hitchhiking, and hierarchical effects also can cause sorting.

While sorting is not an evolutionary mechanism as such, it has specific implications for evolution. The majority of Vrba and Eldredge’s (1984) discussion and the thrust of the present analysis focus on what we call hierarchical sorting. Hierarchical sorting is important to Vrba and her associates because of their view of punctuated equilibrium (Eldredge and Gould 1972) and their belief that evolutionary processes can occur at a variety of evolutionary scales, including the scales of genomes, organisms, populations of organisms, and species. Additionally, they argue that these "evolutionary individuals" can be organized into a hierarchy, as illustrated in Table 4.1 in which the higher constituents comprise groups of the lower constituents (Vrba and Eldredge 1984:149).

Simplifying their discussion somewhat, Vrba and her associates argue that evolutionary changes at one scale can result in changes at other evolutionary scales. Thus, their position is that evolutionary processes operating on species can affect characteristics of individuals and genomes, that evolutionary processes operating on individual organisms can affect the evolutionary characteristics of genomes and species, and that evolutionary processes operating on genomes can affect the characteristics of individuals and species. However, an asymmetry between the effects of sorting at different levels is present. They suggest that evolutionary processes operating at higher levels will necessarily affect changes at lower levels, but evolutionary processes at lower levels may or may not affect changes at higher levels in the hierarchy (Vrba and Eldredge 1984:166; Vrba and Gould 1986:219). In other words, changes in species caused by species-level selection (i.e., punctuated equilibrium) will necessarily affect individual organisms and gene frequencies, but a mutation in a gene may have no effect on the higher levels (Vrba and Gould 1986:219).

The ultimate importance of the concept of hierarchical sorting is the implication that the proximate cause of an evolutionary change at one level may be
changes caused by evolutionary processes operating at different levels in the hierarchy (Vrba and Eldredge 1984; Vrba and Gould 1986). Thus, the cause of phenotypic changes in individual organisms may be the effects of species-level or genetic-level evolution. It is beyond the scope of this chapter for us to evaluate the implications of the concept of hierarchical sorting for the model of punctuated equilibrium. Our goal instead is to show that the concept of hierarchical sorting is a useful one for many archaeological questions of an evolutionary nature. We suggest that hierarchical sorting of behavioral and material phenotypic traits is possible and perhaps frequent in archaeological contexts. The effects of evolutionary processes acting on phenotypic variation at a particular scale can result in patterned sorting of material and behavioral traits at different scales. Because our subject matter has shifted from the biological to the archaeological record, though, the hierarchy proposed by Vrba and Eldredge (1984) and illustrated in Table 4.1 is not applicable. Instead of being concerned with the long-term development of species and the accompanying physiological and genetic changes, we are interested in explaining the changes in behavioral patterns within a specific species, Homo sapiens.

We suggest that the cultural phenomena that are of interest to evolutionary archaeologists can be organized into hierarchies in a manner similar to the biological hierarchy discussed previously. Like the hierarchy proposed by Vrba and her colleagues, we believe that the hierarchy of cultural phenomena can also be divided into relatively discrete levels differing in their inclusiveness. We suggest that these levels are formed by nested hierarchies, as we explain in the following section.

Nested Hierarchies

Evolutionary archaeologists have identified two classes of material and behavioral traits that can be distinguished based on the evolutionary processes that affect them: functional traits and stylistic traits. Functional traits are defined as traits that affect the reproductive success of individuals (Dunnell 1978, 1980) or the replicative success of cultural traits (Leonard and Jones 1987) in a given selective environment. They can be present at a variety of levels. For example, the use of a particular artifact or tool, such as the bow and arrow, or a subsistence strategy, such as maize horticulture, may be functional. However, attributes of a class of artifacts (e.g., temper type or porosity of ceramic vessels) may also be functional.

In contrast, stylistic traits are defined as those attributes that do not affect the fitness of individuals or the replicative success of cultural traits. These traits are not directly impacted by the action of natural selection and are, by definition, free to vary irrespective of the operation of selection. The replicative success of stylistic attributes is instead explained by evolutionary mechanisms such as drift and innovation and the characteristics of cultural transmission systems (Neman 1995).

By definition, all cultural traits have fitness consequences. The weight of atlatl-dart weapon systems and the functionality of projectile point were, therefore, of importance to the survival of the group.

Specifically, arrows are not true barbs. The weight of the dart, balance. An arrow with a high correct flex in the shafts, therefore, cause the chuck-they are more effective than arrow shafts, and an atlatl darts, except in the case of the weight of the two weapon analyses of projectile point.

We suggest that the different levels because it affects the efficiency of point weight is a factor that affect the weight of the weapon that is being used. Arrows and arrows in a group of projectile points would, therefore, be at different levels, the weapon analyzed at another level.

Relationships such as these and the general we examine are material attributes of a combination of attributes. These relationships and the hierarchy are distinguish various attributes in archaeology.
By definition, all functional and stylistic traits have some degree of replicative success (or lack thereof). The replicative success of some traits may be contingent on their connection with other traits, however. For example, all functional traits have fitness consequences, by definition. The effects of different functional traits are not necessarily equivalent, though. Functional traits can also be present at different scales, and the functionality of a particular trait may be manifested only in the presence of traits at higher scales. To illustrate this point, we consider the factors that affect the weight of projectile points. The weight of arrowheads is an important performance characteristic of bow-and-arrow technology, but the weight of atlatl-dart points is not as important a performance characteristic of atlatl-dart weapon systems (Christenson 1986). This difference in the importance of projectile point weight is caused by the different mechanical and aerodynamic characteristics of the two weapon systems.

Specifically, arrow shafts are light and must flex correctly for the arrow to fly true. The weight of arrowheads has a great impact on an arrow’s flex and balance. An arrowhead that is either too heavy or too light will not produce the correct flex in the arrow shaft, will cause the arrow to be unbalanced and will, therefore, cause the arrow to fly erratically (Beck 1998; Christenson 1986; Fenenga 1953). In contrast, the mass of the shafts of atlatl darts is much greater than arrow shafts, and dart points generally do not greatly affect the balance of atlatl darts, except in the case of extremely large and massive points. We expect, therefore, that the weight of arrowheads will be both smaller and less variable than that of atlatl dart points because of the different performance requirements of the two weapon systems (an expectation that has been supported in several analyses of projectile points [e.g., Christenson 1986; Shott 1997]).

We suggest that the weight of projectile points is a functional characteristic because it affects the efficiency of both weapon systems. However, the effect of point weight is different in terms of both its importance and its specific performance requirements for the two weapon systems. The selective forces that affect the weight of the projectile points are contingent on the weapon system that is being used. If natural selection were to begin to favor the use of bows and arrows in a group that had previously used atlatl darts, the weight of their projectile points would change. Thus, the effects of evolutionary processes at one level, the weapon system, would provide the proximate cause for potential changes at another level, the weight of projectile points.

Relationships such as these between the characteristics of projectile points and the general weapon system create a hierarchy in which some behavioral or material attributes are contingent on, or nested within, other more inclusive attributes. These relationships are similar to those presented by Vrba and Eldredge (1984) and Vrba and Gould (1986), in that the different levels in the hierarchy are distinguished by their inclusiveness; higher levels include and integrate those attributes in the lower levels.

We believe that the “scales” created by the asymmetrical relationships of various attributes are not necessarily absolutes, though, because each series of
relationships is unique, based on the behavioral and material traits being examined. For example, the nested hierarchies associated with atlatl darts are different from those associated with bows and arrows, not to mention those associated with ceramics or architectural features. However, we suggest that a general hierarchy will be applicable to most cases (Table 4.2).

Attributes of artifacts will always be lower in scale than the artifact itself. Thus, while attributes of artifacts such as the wall thickness of ceramic cooking vessels may be subject to evolutionary processes, evolutionary changes at the scale of the entire artifact, such as changes in use and the morphology of ceramic cooking vessels, will necessarily affect the individual attributes of the artifact in some way, even if the result is a reinforcement of the existing attributes. Of course, evolutionary changes at lower scales may cause sorting at a higher level, but, as Yrba and Eldredge (1984:166) observe, this is not necessarily so. For example, evolutionary changes in arrow design will necessarily affect projectile points, but changes in projectile points may or may not produce evolutionary changes in arrow design or other components of the weapon system. Thus, the same asymmetry identified by Yrba and Gould (1986:219) is present here: evolutionary changes at a higher level will necessarily impact lower levels, but changes at lower levels may or may not impact higher levels.

Likewise, individual artifacts are at a lower scale, in general, than groups of functionally integrated artifacts. Using the bow-and-arrow example presented earlier, the entire weapon system is at a higher level than that of arrowheads, because the general weapon system includes the arrowheads, but arrowheads are only one component of the integrated weapon system. Finally, functionally integrated artifacts are lower in scale than functionally integrated groups of artifacts. Thus, behavioral and material patterns such as subsistence strategies, which cause the integration of numerous groups of functionally integrated artifacts such as groundstone assemblages, tools used in planting and harvesting crops, and artifacts used for cooking and consuming foods, are at a higher scale than any of the individual artifact groups.

PREVIOUS ARCHAEOLOGICAL DISCUSSIONS OF SORTING

While sorting has never received a systematic treatment in the archaeological literature, preliminary discussions on the subject have been presented by Abbott et al. (1996) McGeimsey (1995), O'Brien and Holland (1990), and Ramenofsky (1995). The present work is largely a continuation of the Abbott et al. (1996) discussion, in the sense that it builds upon the foundation outlined in that work. Regarding McGeimsey’s dissertation work relating to the concept of sorting, we differ simply in our definition of the term “sorting.” We define sorting as the differential persistence of traits, due to linked relationships between traits where at least one trait is affected by either selection or drift. McGeimsey discusses sorting as one of three possible causal mechanisms of evolution, along with

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<tr>
<th>Phenotype</th>
<th>Groups</th>
<th>Functions</th>
<th>Artifacts</th>
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selection and drift. However, the Middle Woodland and hierarchically sorted traits, we would identify some other mechanism. With higher (drift) acting at a different level, that results from this is a causal mechanism of hierarchical sorting (Parry 1998).

The Shift from Foraging to the Southwest

An example of the evolutionary process of stylistic traits affects their colleagues argue that which co-occurs with not be selection for does be favored because and the primary trait and had argued that a shift from differential mobility (Parry and Kelly re- tool technology because. They need an efficiency different implement materials. In contrast, unique costs. They have learned to easily cache large simple, unmodified
Table 4.2

<table>
<thead>
<tr>
<th>Phenotypic Constituents</th>
<th>Groups of Functionally Integrated Artifacts</th>
<th>Functionally Integrated Artifacts</th>
<th>Artifacts</th>
<th>Attributes of Artifacts</th>
</tr>
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selection and drift. His goal is to determine whether lamellar flakes of the Illinois Middle Woodland are a functional adaptation, the result of drift, or simply hierarchically sorted traits. We disagree with McGimsey's discussion only in that we would identify sorting as merely an outcome, not an evolutionary force or mechanism. With hierarchical sorting, the causal mechanism is selection (or drift) acting at a different level in the hierarchy, not the sorting at other levels that results from this selection. Ramenofsky (1995) has also defined sorting as a causal mechanism, but she has since reversed her position and argued that hierarchical sorting is not a separate mechanism from selection (Ramenofsky 1998).

The Shift from Formal to Expedient Tools in the American Southwest

An example of the sorting of two functional traits is presented by Abbott et al. (1996). While this example deals with functional traits subject to the evolutionary process of natural selection, the basic relationship is the same for stylistic traits affected by evolutionary processes such as drift. Abbott and her colleagues argue that the transition from a biface to a flake-tool technology, which co-occurs with maize agriculture in the North American Southwest, may not be selection for flake-tool technology per se. Instead, this technology may be favored because it is linked to the agricultural subsistence strategy, which is the primary trait under selection (Abbott et al. 1996). Previous researchers have argued that a shift from biface to flake production is caused by decreased residential mobility (Parry and Kelly 1987). On the basis of ethnographic analogy, Parry and Kelly reasoned that mobile hunter-gatherers use a formal, biface-based tool technology because of the high costs of transporting stone tool materials. They need an efficient, flexible tool kit from which they can fashion numerous different implements as they cannot afford to carry large amounts of raw materials. In contrast, sedentary farmers do not have to be concerned with transport costs. They have less incentive to maintain a formal technology because they can easily cache large amounts of raw materials from which they can create simple, unmodified flake tools as needed (Parry and Kelly 1987:299).
Abbott and her colleagues agree that the shift to flake-tool technology is indeed related to the change to a sedentary lifestyle, but they argue that sedentism is a proximate-cause, rather than ultimate-cause, explanation of this shift (see Bin Mayr 1982). They propose that flake technology is a by-product of reduced mobility and that reduced mobility is a product of selection favoring a shift toward intensified maize production (Abbott et al. 1996:39). Therefore, flake technology should be interpreted as a sorted trait that is linked to the adaptation of an intensive agricultural subsistence strategy. They caution, however, that this shift in tool technology probably does not represent an example of “pure sorting” (Abbott et al. 1996:39), where the sorted trait is completely neutral. They note that flake technology likely conferred a reproductive advantage to its users (versus those who have no flake technology) and is indeed an adaptation; however, they argue that there is a significant “adaptive differential” (Abbott et al. 1996:39) between the flake and agricultural technologies, with the shift in subsistence ultimately causing the major fitness consequences favoring these linked technologies.

Fitness Coefficients

The idea of adaptive differential introduced by Abbott et al. could be more formally expressed in terms of fitness coefficients. We use the term “fitness coefficients” to indicate a relative measure indicating the differing effects of particular traits on fitness in a given selective environment.” Not all functional traits have an equal impact on fitness in a given selective environment. For example, a car with foiled spark plugs may not run very efficiently, but a car without wheels will not go anywhere at all. Similarly, the shape of a projectile point may have a great effect on the efficiency of the weapon system used for killing game. Raw material used in fashioning the point may also have fitness consequences. However, the use of chalcedony rather than chert may have a much smaller impact on killing efficiency than point shape. If one were to haft a large chopper made of chert onto an arrow shaft and an arrow point made of chalcedony onto another arrow shaft, differences in the performance of the two arrows as long-distance hunting weapons would be due more to tool shape rather than material type.

The significance of the concept of fitness coefficients for our discussion of sorting is that if indeed agricultural technology and stone-tool technology were both important functional attributes under selection, then the shift to a flake-based technology would not truly be an example of sorting. However, if the two attributes had greatly differing effects on fitness, and changes in tool technology were simply an inevitable result of changes in the subsistence system due to significant fitness consequences, then we would classify the shift to flake tools as hierarchical sorting. More specifically, this may be an example of what Vrba and Eldredge refer to as “downward causation,” or sorting of variation at lower levels due to selection occurring at higher levels (Vrba and Eldredge 1986:152).

LINKED REPLICATOR HITCHHIKING

The second cause of linkages in the process of hitchhiking is when two or more traits are linked by natural selection and drift, or trait(s). Just as with the method of describing a relation using hierarchies in the process of hitchhiking, the true causal mechanism is the same: hierarchies of traits, with the hierarchical organization of traits being a specific relation describing a specific relationship. The importance of this distinction is that it brings important concepts into play. Linkage describes a specific relationship between traits, and a specific relationship can describe a specific relationship. Sober (1984:97–102) offers an example of hitchhiking to illustrate this point. If we have a pattern of various colors and sizes of round stones, with holes bored through them, we can imagine that the holes allow us to select and use those stones to fit the holes of other stones. As the stones continue down the river, they may land on rocks, and those stones become part of a matrix of stones that form a hunting tool. We can conceptualize this as a horizontal level of time, and the product of natural selection and drift being a characteristic necessary to connect two in an appropriate size to fit the hitchhiking trait associated with the size of the environment, then, small pebbles are used in the green balls.

Sober’s example can be summarized as follows: For example, in a hypothetical environment, black hunting balls are available; a black granite type of smooth, fine-grained basalt. All of the basalt is smooth and fine-grained, but because of certain properties...
In this case changes in the subsistence system as a whole (a shift to intensive agriculture) effected a change in a particular class of artifacts (stone tools) that were a subset of the subsistence system.

**LINKED REPLICATIVE SUCCESS THROUGH HITCHHIKING**

The second cause of linked replicative success in the archaeological record is the process of hitchhiking (sometimes called piggybacking). With hitchhiking, two or more traits are associated such that evolutionary mechanisms such as natural selection and drift operating on one of the traits also affect the other trait(s). Just as with the concept of hierarchical sorting, hitchhiking is a means of describing a relationship between traits, not an evolutionary mechanism as such. In the process of sorting due to hitchhiking on traits under selection or drift, the true causal mechanism is either drift or selection, not sorting.

Hierarchical sorting could be considered a special case of hitchhiking. However, we distinguish between hitchhiking and hierarchical sorting in order to bring important conceptual details of each into focus. While hierarchical sorting describes a specific relationship between scales of evolution, hitchhiking describes a specific relationship between traits, regardless of their scales. The importance of this distinction is illustrated further in the following discussion.

Sober (1984:97–102) has presented an illustrative example that is useful for understanding hitchhiking traits. He begins by suggesting that a number of balls of various colors and sizes are placed within a cylinder with several horizontal layers, each with holes becoming progressively smaller. Balls that are too large to fit through the holes leading to the next level are trapped, while the smaller balls continue down through the cylinder. After the balls have been separated according to their size, it becomes obvious that only green-colored balls are small enough to reach the bottom of the cylinder.

We can conceptualize the cylinder as the selective environment and each horizontal level as time. Through time, the amount of variation is reduced as a product of natural selection; only a portion of the balls possessed the characteristic necessary to continue to the next generation of selection (i.e., are the appropriate size to fit through the holes). However, the color green is a hitchhiking trait associated with the small balls. Within the hypothetical selective environment, then, small balls are being selected for, but there is a selection of green balls.

Sober's example can easily be transformed into an archaeological framework. For example, in a hypothetical environment, three flaked-stone raw materials are available: a black obsidian, a fine-grained gray chert, and a brown, coarse-grained basalt. All of the raw materials are equally plentiful and equally accessible but provide different performance characteristics. Within the selective environment, the use of fine-grained chert for projectile points is selected for because of certain performance characteristics it provides (e.g., sharp, durable...
edges). The raw material used to manufacture the projectile points (i.e., the chert) is functional, but the color of the raw material is neutral. However, because the chert is gray, projectile point color will be controlled by the selection for the raw materials used to manufacture projectile points. The color of projectile points will, therefore, be a hitchhiking trait created by the selection for chert as the raw material type.

The preceding example illustrates the importance of the process of hitchhiking within evolutionary archaeology. An archaeologist analyzing the projectile point assemblage would quickly observe that the projectile points are made of the gray chert. However, explaining why the gray chert was used to make the projectile points would require a detailed analysis of the selective environment operating on the individuals producing the points, the range of raw materials available to make the projectile points, and an understanding of the performance characteristics of each raw material (Jones et al. 1995). The challenge facing the evolutionary archaeologist is no different from the challenge facing the evolutionary biologist; they must both identify how the phenotypic characteristics contribute to the fitness of the evolutionary individual (Sober 1993). In our hypothetical example, the sharp, durable edges created by the conoidal fracture of the chert are under selection, not the raw material color. However, the one-to-one correlation between raw material type color and the projectile points may lead to the appearance that the color of the points is under selection. An explanation based on this incorrect premise would necessarily be wrong; therefore, it is of the utmost importance that the evolutionary archaeologist correctly distinguishes between functional attributes and sorted stylistic attributes.

We suggest that two kinds of hitchhiking may occur in archaeological contexts: (1) hitchhiking by historic contingency and (2) hitchhiking by mechanical constraints. Hitchhiking by historical contingency occurs when two or more attributes, regardless of whether they are stylistic or functional, are associated such that when one of the traits is manifested, the other trait(s) is (are) as well, simply due to a chance historical association between the traits. In contrast, hitchhiking due to mechanical constraints occurs when two or more traits are mechanically connected in some way such that evolutionary changes in one trait necessarily will impact some aspect of the manifestation of the other trait(s). We discuss each of these causes of hitchhiking next and present examples of their operation.

Hitchhiking by Historical Contingency

Because evolutionary processes do not direct innovation, they must operate on the variation that is present within the historical context (Dunnell 1980; Leonard and Jones 1987). If two or more traits are connected such that the manifestation of one by chance includes the manifestation of the other even if the connection is not mechanically necessary, and an evolutionary process favors one of the traits within the association, the remaining trait(s) will also be favored. Correlation between traits can be due to linkage (Falconer and Mackay 1996) or may be due to the entities selected for the traits. Genetic linkage, is important for hitchhiking.

Linkage of traits in the biogeographical drift (Falconer and Mackay 1996) may be a significant factor in cultural adaptation size, or the number of traits. On a regular basis, if a trait is large, drift can still play a role.

Two kinds of sorting may occur in linkage of traits. If a neutral trait is linked to a functional trait, the functional trait will expand the neutral trait is linked to functional traits. In some cases, the concept of sorting of phenotypic traits, while the evolution of other traits is selection.

We presented an example of hitchhiking of flaked-stone tools as sharpness and durability. We explain why a trait that is not raw material color, may be a style may appear to be introduced. A new trait may be linked by chance. If the linked drift rather than a genetic change has not been examined into the linkage, the concept of linked equilibrium models used.

Linkage disequilibrium is a significant, nonrandom process. This means that selection may occur with each other. When equilibrium should decrease during the formation of the equilibrium (1989:47–48). Understanding out mating barriers results in an increase or decrease in variation and more variation and more variation.

This aspect of linkage is...
vered. Correlation between genetic characteristics is attributed to pleiotropy and to linkage (Falconer and Mackay 1996:312). The first factor, pleiotropy, is discussed in the section on sorting due to mechanical constraints. The second factor, linkage, is important for conceptualizing sorting due to historical contingency.

Linkage of traits in biological populations is attributed to chance, or random genetic drift (Falconer and Mackay 1996:16; Hartl and Clark 1989:131, 489). Drift, or sampling error, in small populations may lead to linkage as some genetic characters drift together to high frequency simply due to chance (Hartl and Clark 1989:54, 131, 489). Neiman (1995) has argued that drift may be a significant factor in cultural evolution because it is a product of effective population size, or the number of people who actually interact socially with each other on a regular basis. Thus, even though nominal population sizes may be large, drift can still play an important role (Neiman 1995:10).

Two kinds of sorting due to chance historical contingency may occur. First, if a neutral trait is linked to a functional trait by chance, then selection for the functional trait will explain the replicative success of both traits. Second, if two neutral traits are linked by chance, they will appear to drift together. In both cases, the concept of sorting is used to explain only the shared fate of the linked traits, while the evolutionary mechanisms responsible for the differential survival of the traits are selection or drift.

We presented an example of this first kind of sorting in our discussion of the hitchhiking of flaked-stone tool color with tool performance characteristics such as sharpness and durability of edges. Sorting by historical contingency may explain why a trait that is neutral in a particular selective environment, such as raw material color, may appear to be under selection due to linkage to functional traits, such as sharpness or durability. Similarly, traits such as ceramic design style may appear to be under selection when they are simply linked to the introduction of a new temper type or firing technology.

Two or more neutral traits, such as painted pottery design elements, may also be linked by chance. In this case the traits will appear to sort together due to linked drift rather than to selection acting on one of the traits. Such patterning has not been examined as yet, but we can suggest at least one useful application of the concept of linked drift, deriving from the expectations of linkage disequilibrium models used in population genetics.

Linkage disequilibrium is a term used to describe a condition wherein there is a significant, nonrandom association between alleles in the formation of gametes. This means that some alleles at different loci on chromosomes tend to co-occur with each other. In populations where mating is random, linkage disequilibrium should decrease over time as a result of recombination of alleles during the formation of gametes (Falconer and Mackay 1996:17; Hartl and Clark 1989:47-48). Understanding why this should be so is simple: a population without mating barriers results in a larger interacting gene pool, which contributes more variation and more possible recombinations in the formation of gametes. This aspect of linkage disequilibrium makes it a useful concept for archaeolog-
Hitchhiking by Mechanical Constraints

Unlike sorting by historical contingency, hitchhiking by mechanical constraints occurs when the manifestation of an attribute(s) that is being affected by evolutionary processes directly affects the range of possible variation in other attribute(s). In biology, such a condition is described by the term pleiotropy. Pleiotropy is a situation in which a single gene, or cluster of genes, may have multiple phenotypic effects. With pleiotropy, selection for one trait may mechanically affect other traits that are not under selection. Sober provides the example of the correlated relationship between the human jaw and chin. He argues that there “never was selection for having a chin, rather selection for certain other features of jaw structure yielded a chin as an inevitable architectural consequence” (Sober 1984:24). As a result chins may appear to be selected for, when they are merely part of a package of traits linked by “architectural constraints” (Sober 1984:24), and other traits in the package are the target of selection. We suggest that cultural traits may also exhibit a condition analogous to pleiotropy that we call sorting by mechanical constraints. For example, basal width places a constraint on the size of the hafting notches in side-notched projectile points. The notches cannot be deeper than the point is wide, or the point will simply be broken into two parts. If basal width is functional within a hypothetical selective environment, but notch depth is not, notch depth may still be impacted by the action of natural selection affecting basal width. Thus, stylistic traits can be sorted through limitations created by the mechanical constraints of artifacts. (See also VanPool’s discussion of metate traits in Chapter 7 in this volume for an additional example of this type of sorting.)

CONCLUSION

We have argued that sorting is an important concept for archaeological explanation. Of primary importance are the consequences for the assignment of cause in evolutionary explanations. Dunning (1978) argued against the adaptationist bias of processual archaeology and proposed that a large part of the archaeological record may be composed of nonfunctional variation that cannot properly be explained as adaptations. Explanation of such variation relies on mechanisms such as random cultural drift, rather than selection. Williams (1966) also provides support for this position, based on the principle of parsimony: “Parsimony demands the prevention of unnecessary events and can be ruled out as an explanation for many archaeological observations” (1966:23).

If stochastic components of design and construction are accepted, then the argument that all design must be adaptive can be rejected. We suggest that parsimony, not competition, is the key factor used to explain different patterns of design or drift in regional social interaction.

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NOTES

1. The appropriate term for a genetically determined equilibrium is genotypic equilibrium and genomes in stable, though not necessarily equilibrium, populations as Eldredge 1984: We use the term “adaptation” to suggest that we are endeavoring to use the term “adaptation” as it is used in biology because it is the most commonly used term in the field.

2. Terms such as memory (Lalande and Eldredge 1982) and types of phenotypic heritability (Slatkin 1985) are debated in biology. We refer the reader to those works (Slatkin 1985; Lalande and Eldredge 1982) to resolve the issues, but we believe all geneticists, therefore, should be familiar with these topics.

3. Our use of the term “ancestral coefficients” of biological or cultural genes is appropriate. We use fitness coefficients to refer to traits in the same genetic context.

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"Parsimony demands that an effect be called functional only when chance can be ruled out as a possible explanation" (Williams 1966:261, emphasis added; see also Selander 1985:87-88).

If stochastic change in neutral variation can explain the patterning in a succession of design styles, drift is a more parsimonious explanation than is a causal argument that attempts to explain the change as a functional adaptation. We suggest that parsimony also demands a consideration of various kinds of sorting to explain differential replicative success, rather than the assumption that selection or drift is necessarily acting directly on a particular trait at a particular level.

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NOTES

1. The appropriateness of the concept of species-level evolution as stipulated by punctuated equilibrium (Eldredge and Gould 1972) or even evolution at the scale of organisms and genomes is still an open debate in biology (see Dawkins 1982, 1989; Vrba and Eldredge 1984; Wilson 1994). Our discussion of Vrba and her associates is not intended to suggest that we agree that species-level evolution is common or even possible. Instead, we are endeavoring to provide a complete discussion of the concept of sorting as it is used in biology before we discuss its applicability to archaeological research.

2. Terms such as those presented in Table 4.2 are similar to the terms used by Vrba and Eldredge (1984:149) in that they are only general terms that can refer to different types of phenotypic structures based on the situation. One need only examine the ongoing debates in biology surrounding the appropriate definition of terms such as species (Hull 1994; Mishler and Donoghue 1994) or, for that matter, genomic constituents (Dawkins 1982, 1989) to realize that these terms are largely defined in case-specific contexts and, therefore, do not differ greatly from terms such as artifacts or attributes of artifacts.

3. Our use of the term “fitness coefficients” should not be confused with the “selection coefficients” of biologists. A selection coefficient is used to express the relative strength of selection pressure on a particular trait in different selective environments, whereas we use fitness coefficients to express the differing impact on fitness of different functional traits in the same selective environment.

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