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Darwinism and its Influences

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Abstract and Keywords

This chapter explores just what is, and is not, a Darwinian explanation in the archaeological context. It does this by reviewing attempts to use Darwinian explanations in the archaeological context, and showing ways in which they have been successful or otherwise. The chapter proceeds by working through historical case studies in archaeological theory, showing how these attempts to apply Darwinian ideas to archaeological data have run up against serious limitations. Typically, they have either assumed natural selection or failed to adequately specify the relevant selective environment. We then offer an alternative view of evolutionary processes—niche construction—that takes history and culture seriously. In so doing, the chapter demonstrates both Darwinism's promise but, just as importantly, its limits as an explanatory framework in the social science context. In particular, we stress the need to show selection is in operation, rather than presuming it, and that at certain scales, and for certain purposes, Darwinian explanations may fail to capture the correct grain of analysis: Sometimes, archaeology is history, and as such, it is interested in explanations that are local, unique, and idiosyncratic to the culture concerned.

Keywords: Darwinism, Darwin, selectionist, cultural evolution, evolution, natural selection, biology, lineages

Cultures change, and the material culture that archaeologists study show evidence of that change. But not all change is evolutionary change. So the aim of this chapter is to explore the extent to which evolutionary models explain or illuminate cultural change. This chapter will deal with three views that directly build on Darwinian natural selection, and crucially, it will examine the limits to such models as explanations of culture and cultural change. Mixed models such as dual inheritance address these limits in more detail, and are dealt with elsewhere in this volume.

There are three broadly positive views. The first is that natural selection is relevant to cultural change because humans are naturally selected animals. Selection has shaped human phenotypes, and those phenotypes are causally relevant to culture and changes in culture. For example, it has been argued that human males have been sexually selected to engage in expensive displays, because high-cost displays are honest signals of male quality (Miller and Boden 2000; Ridley 1994). In some contexts, those displays might involve the production of artefacts whose character testifies to the skill or the wealth of their creator (see e.g. Kohn 2000; Kohn and Mithen 1999). Such displays leave traces in the physical record—traces that can be understood only by understanding their function as sexually selected displays. On a second view, populations of artefacts—cultural traits—are copied down the generations, and so artefacts themselves form Darwinian populations. On this view, flint daggers themselves evolve, as some variants in a dagger population are copied more frequently than others (perhaps because they persist longer without breaking; perhaps by good luck). Cultural change itself is Darwinian. We are self-confessed partisans of the third view, the idea that the separation of humans from their culture is false. What makes humans human is the fact that they are deeply embedded within, shaped by, and adapted to culture. Humans have co-evolved with their cultures. We have made our cultures; but once made, cultures become both a

central feature of human selective environments and a second mechanism through which children are similar to their parents.

After a brief introduction, this chapter will explore these alternative ideas within the archaeological context. In the final section, we will outline the current limits to Darwinian theory in archaeology.

Introduction

As long as there have been Darwinian ideas, there have been purportedly Darwinian views of the human past. Especially in the late 19th and early 20th century, many of these were misguided, and in some cases they were vehicles for abhorrent ideological views. Reactions *against* these ideologies have left a legacy of suspicion or worse, to Darwinian ideas in the social sciences. This hostility was re-inflamed by the sociobiology debates of the 1970s and 1980s. Part of the goal of this chapter is to show that this reaction is unwarranted. Modern Darwinian theories will not absorb the social sciences. They will supplement them, providing them with new tools, and new opportunities. But—and this is crucial—Darwinian views have much to learn from the social sciences too.

The social sciences have other reasons for scepticism about Darwinian approaches. Oxygen in the atmosphere is a necessary condition of fire. But when trying to explain, say, the Australian wildfires of 2009, being reminded of that is not informative or insightful. Likewise, (according to many) the evolution of intentional, highly social agents is a necessary condition for the formation or change of *any* human culture. But evolutionary theory does nothing to explain the specific shape of a culture. Within the archaeological context, the interpretive archaeological framework of such people as Ian Hodder (Hodder 1997; Hodder and Hutson 2003) best exemplifies this scepticism. As they see it, Darwinian theories at best provide limited insights into the social systems of the past, and at worst they are misleading.

Darwin's original insight was to combine two ideas, natural selection and the notion of common descent: a tree of life. Common descent and the tree of life provided biology with an important set of tools for classification and understanding the past, for one can compare lineages to estimate how closely they are related, and how their differences have arisen. One can sometimes even estimate the date of divergence, so these methods provide insights into many important features in biology. The notion of lineages is also useful in understanding cultural relationships. For instance, cladistic methods have been used with great success to understand the history of language families (Gray and Atkinson 2003; Gray and Jordan 2000). Combined with other lines of evidence, language trees can give clues about the origins and movement of peoples (Kirch and Green 2001). But people who use such trees are careful to note that there is no implication of evolution *by natural selection* in the use of such tools. Lineages may change for a number of reasons, and Darwinian natural selection is not a precondition for the use of cladistic analysis. In fact, in constructing molecular clocks, it is important to identify genes that are not under selection. One can emphatically deny a role for Darwinian natural selection in human material culture change, whilst still using cladistic methods derived from biology. Archaeological theorists occasionally overlook this distinction, and the result has been that proponents of Darwinian ideas have used lineages and phylogenies as examples of the utility of selectionist ideas, when they actually show the utility of tree thinking. Inheritance allows us to identify cultural lineages, but that does not show that these lineages evolve by natural selection. The two issues are distinct.

To understand the potential of Darwinian theories in archaeological contexts, we will work through three case studies of archaeological approaches that, while interesting in their own right, also highlight a potential role for Darwinian natural selection. We start with processual archaeology, which provides us with a somewhat simplistic view of the relationship of cultural products to the environment and then look at two explicitly Darwinian approaches.

Having examined these alternatives, we provide an outline of how a good Darwinian theory in archaeology should work—one which relies on a new approach in evolutionary biology known as niche construction theory.

Processual archaeology and biology

Processual archaeology took two central ideas seriously: that archaeology was anthropology, and that

archaeology should be scientific. But one aspect of processual archaeology that is sometimes overlooked is its relationship with Darwinian ideas. Lewis Binford and others engaged in the 'New Archaeology' of the 1970s were not explicitly Darwinian, but they were adaptationists; they thought about culture in functionalist terms. Binford explicitly described culture as an integrated, systemic, adaptation (Binford 1962)

There had been a robust history of functional approaches in archaeology (Trigger 1990). Graham Clark and others had long recognized the importance of the environment as a source of insight into the past (Clark 1965). Material culture helps individuals cope with the physical world, and so we can understand a culture by seeing how it embodies a functional response to that world. A core concern of archaeology is to explain how people made a living: how they managed the business of surviving in the world. Binford's innovation was to move beyond an individualist perspective. He did not just see individual behaviours and technologies as adaptations to the environment; he saw the entire cultural system as an adaptation. If Binford were right, it would be possible to understand *all* aspects of a culture as mechanisms for ameliorating environmental impacts.

Processual archaeology advanced archaeology. It made archaeologists think deeply about evidence and hypothesis testing. But the adaptive view of culture was less appealing, with too simple a picture of the selective environment driving functional response and too little attention to historical legacies that influence and constrain response. Moreover, this view lacked an explicit and defensible model of the competing populations shaped by selection. By understanding the limits of processual archaeology's functionalist thinking, we will develop a clearer idea of how to better integrate Darwinian ideas within archaeology.

What is the environment?

What constitutes the environment? A simple view identifies the environment with the physical environment: the arctic wastes, the deserts, the jungles, the temperate forest. The environment is a climatic and perhaps biogeographical challenge that has to be overcome. The environment so understood clearly does have a relationship with human material culture. Humans use material culture to cope with the vagaries of climate, temperature, and so forth. But though there is a relationship between material culture and physical environment, there is no unidirectional arrow from environment to culture. Culture is not simply an adaptation to the physical environment. It is a mistake to think that archaeologists need only to develop models of the relationships between these environmental demands and cultural practices, and so see material culture as mediating between human needs and physical realities. Processual archaeology tended to see the environment in this simple way, as primarily the physical environment. Binford's 2001 book *Constructing Frames of Reference* can be seen in this light. He aimed to document many case studies of environment-culture relationships, and to build a theory of cultural adaptation from that data.

This is too simple a picture of the selective environment to which culture is a response. It ignores important social features of the world. Most obviously, groups subject to demographic pressure sometimes compete, arm themselves, and defend themselves. The environment includes other humans, their actions and products.

What's more, history matters. Groups retain historical legacies long after they migrate to new areas (Guglielmino et al. 1995). Consider, for example, the Norse expansion to Greenland. The failure of the settlement was in large measure due to historical legacies constraining adaptation to physical conditions (Diamond 2006; Jones and McGhee 1986). Explaining the failure of the Norse settlement requires us to identify the interactions between history, culture, and physical context, and this is typical rather than exceptional. As in the biological world, even when it is important, natural selection is not the only factor explaining trajectories of change (Sterelny 2007). History, understood as an idiosyncratic trajectory through time, helps shape possibility, and that is true of organisms, individual humans, groups, and cultures.

These omissions of adaptationist processual archaeology pose an important general question for any version of Darwinian archaeology. What is the selective environment that shapes human material culture?

The grain of analysis

Processual archaeology conceives of a culture as a single adaptive system. This model exaggerates the extent to

which cultures are integrated. If it were right, cultures would be so integrated that any change in one part of the system would have ramifications elsewhere, and change would be slow or impossible. This is clearly wrong. History, contemporary ethnography, and anthropology all reveal that some cultural elements change remarkably quickly. This is particularly true of functional elements of cultures, where the adoption of new technologies can be extraordinarily rapid in some cases, even while the less clearly functional, more stylistic elements of a culture remain stable (Shennan 2008; Rogers and Ehrlich 2008). It is these distinctive rates of change *within* cultures that have allowed archaeologists to determine cultural lineages from the Cultural Historians of the first half of the 20th century to archaeologists of today (Childe 1929; Trigger 1990; O'Brien, Darwent, and Lyman 2001; O'Brien et al. 2002).

We should not treat cultures as a single adaptive unit. Perhaps instead we should see components of culture as independent adaptive traits, with each individual trait subject to its own adaptive trajectory. This would integrate functionalist thinking better with contemporary Darwinism. For natural selection implies the existence of a population of competing agents, some doing better than others, with the traits of the more successful competitors being preserved and amplified by selection (Sterelny and Griffiths 1999; Godfrey-Smith 2009). If the *entire culture* is the unit of adaptation, selection would have to act on a meta-population of cultures. While that might sometimes be possible, it requires special conditions. Thus Binford's functionalist thinking raises a second issue for any Darwinian, selectionist approach to archaeology. Darwinian natural selection requires a population that varies in fitness. What is the population under study in Darwinian archaeology? The processual archaeologist seems to be committed to a meta-population of cultures. But there are other possible populations available. In most biological models, Darwinian populations are populations of individual organisms, and that is an option for the Darwinian archaeologist as well. There are others. Some evolutionary biologists have argued for populations of genes, and in archaeological contexts, some have suggested artefacts themselves, memes, and various other cultural constructs as 'individuals' in an evolving populations (Maschner 1996). There are a number of alternatives, and these options are not mutually exclusive.

This analysis of processual archaeology thus gives us two crucial questions to bear in mind in our ongoing analysis: we must identify the selective environment, and we must identify Darwinian populations and their members. These questions are not independent: the identification of Darwinian populations has implications for our view of selective environments. Suppose Darwinian populations are composed of individual humans. Then the material culture characteristically used by that population is part of the selective environment. An individual incapacitated by seasickness is unlikely to do well in a culture where ocean-going technology is the dominant subsistence tool, nor is one without lactose tolerance in a population of cattle herders (Durham 1991). Alternatively, if tools themselves are parts of evolving Darwinian populations, then human psychology is part of the tools' environment. Functionally equivalent, yet aesthetically distinct, tools may be under different selective regimes, as one tool appeals to the aesthetic preferences of its users.

To explore these ideas further, we will look at two theoretical positions that both claimed to be Darwinian. Despite this commonality, there is a fascinating history of debate between proponents of these views (Boone and Smith 1998; Lyman and O'Brien 1998; Lyman and O'Brien 2001; O'Brien 1996a; Shennan 1996). This debate helps shed further light on the limits, problems, and prospects for Darwinian theory in archaeology.

Evolutionary archaeology

One project of archaeology is to explain change over the long term, for archaeologists generate long-term data sets. Archaeologists identify changes in artefacts at different layers, and they need a mechanism to explain these changes. For archaeologists who looked to the sciences for their explanatory forms, evolution by natural selection might provide that mechanism.

V. Gordon Childe and others were aware of the potential of evolutionary ideas to aid archaeological explanations of change, even if they equivocated on the role of Darwinian ideas in the archaeological context (Trigger 1990; Childe 1963; Trigger 1980). So it is not until the 1970s that we see the most explicit attempts to apply Darwinian ideas to archaeology. A key figure in evolutionary archaeology was Robert C. Dunnell, later followed by David Rindos, R. Lee Lyman, Michael O'Brien, among others (Dunnell 1971; Dunnell 1996a; O'Brien 1996b).

The idea seems fairly straightforward: natural selection will shape populations of artefacts in the same way that it

does populations of organisms. Artefacts that are less adaptively fit will not be copied. Those that are adaptively fit will be copied more often and, in effect, out-compete other artefacts. We should expect to see changes in populations of artefacts over time.

Put so generally, the idea seems plausible. It seems to provide the mechanism required to explain change. But difficulties arise when we probe the basic picture about the nature of the Darwinian population, the relevant environment, and the method of replication from generation to generation. For Robert Dunnell and the selectionist archaeologists, Darwinian populations are populations of artefacts.

Evolution is change in the composition of a population over time. In evolutionary archaeology, the population is artefacts.

(Lyman and O'Brien 1998)

The choice of artefacts is a key theoretical commitment of this particular school of archaeological thought. On this view, human culture evolves, potentially independently of humans themselves. The hard parts of human material culture which archaeologists see are fossilised remains. It is not completely clear what these fossil artefacts are fossils of: behaviours, ideas, memes; cultural variants of some kind. Dunnell-style evolutionary archaeologists do not think this ambiguity matters.

Paleobiologists do not worry about the reproduction of particular replicators—genes—when they study fossil organisms. A bone or tooth is not a replicator; it is part of an organism's phenotype. Whether a tooth represents one or multiple genes is as yet unknown, but this does not keep paleobiologists from trying to determine and explain the evolutionary histories of the organisms whose phenotypic hard parts they study. Similarly, artifacts are not replicators; they are what is replicated.

(Lyman and O'Brien 1998)

On the view of evolutionary archaeologists then, archaeologists can view the changes in the archaeological record the same way as evolutionary biologists view the fossil record. They can be neutral on whether a potsherd or flint flake represents a particular behaviour, an idea, or a meme. On their view, the original living culture was evolving, and artefacts are evidence of that evolution.

The difficulty is, of course, that we cannot assume the changes they document show evolution by natural selection, the evolutionary archaeologists supposed mechanism of change. As noted in the introduction, ancestor–descendant relationships—lineages—can form without natural selection occurring. They need to show, rather than assume, natural selection acts in human cultures, where individuals can make decisions about their world. Change can be the result of individual rational assessment. Evolutionary archaeology backgrounds human decision making; it plays a tacit role as part of the selective environment

For many people, this is simply the wrong explanatory strategy. Human decision-making, humans' acts of choosing, should not be in the background; human agency should be in the foreground of an explanation. An explanation of Stonehenge that says: 'It was made because the behaviour involved appealed to the makers' underlying psychological dispositions towards collective behaviour' tells us nothing specific about the proximate set of beliefs that actually guide the behaviour of the individuals concerned. A religious artefact is made by individuals to propitiate a potentially angry god and not, at least in their own mind, to act as a communal social marker. At the very least, Dunnell-style evolutionary archaeology needs an explicit and well-motivated account of the population-level process of variation and selective retention in artefact populations, and of the relationship between such population-level processes and deliberate agent choice.

Still more challenging is the fact that many elements of human culture do not change by natural selection. Even evolutionary archaeologists accept this fact. Dunnell and others distinguish between stylistic elements and functional elements of cultures (Dunnell 1996b). Stylistic elements,—decoration, iconography, and the like—do not seem to be under selection at all. For that reason, they are useful in determining cultural relationships. Whilst functional technology is highly responsive to new situations and opportunities, stylistic elements are often not. Leonard, for instance, uses stylistic elements to identify cultural lineages, thus solving a mystery of the cultural origins of a particular group (Leonard, 2001). Kirch and Green apply similar ideas to the origins of Polynesian cultural groups (Kirch and Green 2001). In these projects, it is important to identify cultural variants under selection

only to exclude them from phylogenetic tree building. A complication for such projects, though, is that there is no sharp distinction between supposedly functional responses to the environment and stylistic traits. The West's addiction to red meat is a case in point. Westerners eat more meat than is strictly necessary, and at huge economic and environmental cost. Diets, too, are to some extent arbitrary and 'stylistic' in the sense implied by Dunnell.

Evolutionary archaeology is thus problematic. It is not explicit about the makeup of Darwinian populations, or selective environments. In many cases, Darwinian archaeologists merely assume natural selection is operating. If everyone in a cold climate chooses to wear warm clothes, natural selection is not operating on the population of garments, selecting against surf shorts and bikinis. Warm clothes are not the amplified survivors of a garment population that included beachwear in the way that polar bear fur is the amplified fur of brown bears. People are choosing to wear warm clothes because of a common feature in the world which they consciously recognize and respond to.

We agree that natural selection may well have shaped the history of some artefacts. The pre-human stone tool record might be a case in point (Jeffares 2010). But the role of selection must be shown, not assumed. In particular, if conscious choice is to be excluded as an alternative explanation, selection must depend on the performance of the tools, but without those performance differences being salient to the tools users and makers themselves. For example, we can envisage a situation where individuals make fishhooks. Suppose they manufacture a new fishhook that is the average shape of the fishhooks of their immediate acquaintances. So, the fishhook manufactured is typically the 'sum' of the design variables of its immediate neighbours. The fishhooks are then deployed, and some break, no longer to act as templates for further manufacture. The survivors that make it back to base become available as templates. Surviving fishhooks are likely to be replicated. In such a situation, there is selection for design variables that assist in hook survival (and, notably, not hook efficiency.)

One suspects, however, that situations such as this are extraordinarily rare. Humans frequently recognize that different cultural traits have distinct payoffs and distinct benefits. The default choice should be that culture is the result of human choices, actions, and decision-making. So we now turn to an alternative view of the role of natural selection—a view which suggests that natural selection has shaped human decision-making capacities and hence, culture and cultural change.

Behavioural ecology

An alternative to evolutionary archaeology has been to utilize the tools of human behavioural ecology. Human behavioural ecology has been influential in anthropology (Winterhalder and Smith 2000), and it has some success within anthropology and archaeology.

Human behavioural ecology is a cost-benefit analysis of strategies available to individuals. The models assume that individuals can recognize the options available to them, assess the probable payoffs to each option, and rank the results. These models have their original home in evolutionary ecology, where it is assumed that animals find near-optimal strategies through variation and selective filtering at the level of populations. There is genetically based variation in behavioural dispositions, and the descendants of those animals lucky enough to have the fittest dispositions come to dominate the population. Individual adaptability does not typically play a central role in models of animal behaviour.

Humans can act adaptively even in relatively novel circumstances. So, in the human case, the background assumption is that learning plays a pivotal role. Given some time to learn, humans typically make adaptive choices. Natural selection does not directly explain *specific* cultural practices; it explains human motivations and capacities to learn.

Behavioural ecological models simplify and that is their strength. They make puzzling behaviours a little more empirically tractable. A cost-benefit model of differing options guides our understanding of choice. Even mismatches, where an organism engages in sub-optimal behaviour, can be informative, revealing subtle constraints on the option pool, hidden costs or benefits, or limits on information.

Behavioural ecology can explain change over time, on varying scales. Over a seasonal cycle, the likelihood of

prey encounters for a predator may vary. Seasonal migration changes the makeup of the local prey populations, and hence the encounter rate. So the optimal strategy at different times of the year may vary, and this helps to explain differing patterns of behaviour. Behavioural ecology models can also help explain the economics of stone tool making. By identifying the costs of gathering raw materials, of manufacture, and of tool failure, we begin to understand (for example) the conditions under which it pays to make specialist tools, or those in which it is worth sourcing high-quality raw materials (Hiscock 2006; Jeffares 2010; Odell 1996). Behavioural ecology can help explain long-term changes in patterns of behaviour. For example, behavioural ecologists see the 'Broad Spectrum revolution'—the expansion of the human resource base—as a response to the declining return rates of formerly favoured prey (Stiner et al. 1999; Stiner, Munro, and Surovell 2000).

Behavioural ecology allows humans to be actors, and active. It puts humans back in the centre of the equation, and, what is more, it puts them back as decision-making individuals. This is all to the good. It captures an important explanatory dynamic, a dynamic that recognizes humans as thinking agents.

Moreover, these models can test processual archaeology's ideas about the relationship between human needs, material culture, and physical environments. Behavioural ecology when applied to archaeology is the natural inheritor of processual archaeology, for it too takes very seriously the notion that culture is an extra-somatic adaptation. But in contrast to processual archaeology, the models of behavioural ecology are designed to take into account adaptations to group living—to incorporate the fact that other members of the species are part of the environment for an individual organism, and constrain the available options for individuals. As evolutionary game theory makes clear (an important tool of behavioural ecology), the costs and benefits of one agent's choice often depend on the choices of others (Ridley 1997; Axelrod 1984; Skyrms 1996; 2004; Calcott 2008). So, human behavioural ecology gives archaeologists formal tools to make functionalist ideas precise, and formal tools to expand their conception of the selective environment.

However, the approach faces some challenging questions. Suppose it turns out that a particular cultural practice—say, fermenting maize before eating it—does maximize fitness, because fermentation adds a particular class of nutrients that are otherwise in short supply in the agents' diets. Of the available options for using maize, agents choose the best. But maize fermentation is not a hard-wired response that has out-competed alternatives in ancestral populations of maize harvesters. So how does the fact that fermenting maize maximizes agents' fitness explain the cultural practice of fermentation?

Fitness does not explain the practice via conscious choice, because agents consciously try to maximize their fitness. Very likely, from their perspective, maize fermenters process maize this way because it is their custom, or because they prefer the taste to other options. The proximate beliefs and motivations of agents are rarely about fitness. Even when they are (as they might be in, say, decisions about health of birth spacing), it is the *beliefs* about fitness that explain a decision, not fitness itself.

It is common within evolutionary biology to distinguish proximate from ultimate explanation of phenotype. A developmental biologist's explanation of the patterning on a moth's wings complements a selective explanation in terms of camouflage, rather than replaces it. Human behavioural ecologists, likewise, can appeal to the complementarity of ultimate, selective explanations of behaviour with proximate ones. Fitness and taste preference can both explain maize fermentation. But this is not a free lunch. Any such idea is committed to the existence of mechanisms that ensure that proximate motivation tracks fitness interests, and that beliefs robustly track costs and benefits. These tacit empirical commitments are far from trivial. Human motivation is plastic: we learn our wants. The process that maintains a cultural practice within a population on a day-to-day level can be very different from the long-term, statistically slight advantages gained in fitness. So why choose fitness as our explanation of the cultural practice? Why not choose the proximal beliefs?

Moreover, humans live in a complex and confusing world (and it is far from obvious that we are good intuitive statisticians). So how do humans come to be as good at making rational bets as human behavioural ecology supposes?

There are also methodological difficulties in applying behavioural ecology models to real-world cases, for it is almost always impossible to directly measure fitness. It must be measured indirectly, by choice of a measurable proxy that co-varies with fitness. Thus in optimal foraging models, calories are often counted, on the reasonable assumption that these are a currency that typically acts as a proxy for fitness. But while in some cases, calories

can act as a currency, some important and fitness relevant human resources cannot be tracked by calorie counting.

Humans often pursue social inclusion, status, and prestige. These social resources make a difference to fitness, and sometimes agents actively sacrifice calories in favour of these benefits. Within anthropology, for instance, some have argued that large game hunting is not in fact the optimal strategy for protein acquisition, and yet the groups involved do hunt larger game. The empirical situation is controversial. But even if the sceptics about hunting are right, the hunters may still be acting optimally. There are times when social or mating demands may override other needs. Actions with energetic costs may accrue other benefits. Kohn suggested that one of the functions of the later Acheulean handaxe was social prestige, rather than protein acquisition (Kohn 2000; Kohn and Mithen 1999). But while it is clearly true that a successful human life depends on the acquisition of a variety of material and social resources, and very long-term trade-offs between current and future benefit, that insight does not help in making the models of human behavioural ecology empirically testable. When strategy choice involves sacrificing one resource in favour of another, the common currency is fitness, and in these choice contexts, fitness may have no measurable proxy. This problem is far less pressing for the behavioural ecology of other animals, as their lives involve far fewer kinds of resources.

Mismatches between the predicted optimum and the actual behaviour can give us some traction on this problem. When observed behaviour diverges sharply from a model's predictions, one possibility is that costs and benefits have been misidentified—as, perhaps, with large game hunting. So sometimes we can tell that our proxy for fitness is too simple, but it does not follow that we can improve it. We would need not just to measure (say) prestige rewards, but also to estimate the value in calories of a prestige increment.

Behavioural ecology shares with processual archaeology a tendency to treat the environment as an external source of constraint on human action: these are 'outside-in' models with a causal arrow from the environment to behaviour. But humans, individually and collectively, change their world. We consider Darwinian approaches to two-way causal interaction in the next section.

Niche construction

One thing that should be clear from our analyses thus far is that human culture, and human intentionality, complicates the application of Darwinian ideas to the archaeological record. Dual inheritance theory is one solution to this complexity. Dual inheritance theories acknowledge that human culture is the result of a complex interaction between two inheritance mechanisms, the biological and the cultural. It provides models of these interactions, and it rightly merits more detailed treatment elsewhere in this volume. But those interactions are not exclusively that of natural selection, and dual inheritance theory frequently recognizes limits to natural selection, and the ways in which culture obviates or insulates human behaviour from natural selection. It also acknowledges that some of those interactions will not be Darwinian, for human intentionality, and human choices, can shape those interactions, and we sketch this in a subsequent section. Our focus here is on the narrower band of processes that are in Darwinian, and in this section we outline how culture can act as a selective environment, shaping the human phenotype.

The theory of niche construction recognises that individuals modify their environments. A burrow, for example, alters the impacts of physical and biological variables on the wombat who makes it. For example, wombats in their burrows often survive wildfires that would certainly be fatal if they were exposed above ground level. Such environmental modifications ('ecological engineering') affects the life of the engineer. But such modification can both ramify and persist, affecting other agents and the next generation. Earthworms are a classic example. They modify their environment, aerating and mixing the soil, and it is this modified environment to which subsequent generations of earthworms must adapt (Laland, Odling-Smee, and Feldman 2000; Odling-Smee, Laland, and Feldman 2003). Moreover, aerating and mixing the soil impacts on virtually every organism that uses that soil, not just the earthworms themselves. Likewise, beaver dams alter the environment of every organism that lives in a dammed stream. In some cases, niche construction is active: a migrating bird changes their environment by moving from one ecological area to another. It adapts by changing in its behaviour to find an environment more suitable. But this migration changes the niche for subsequent downstream generations as well as for the individual.

Humans are niche constructors *par excellence*, in four respects. First, humans both cooperate and use

technology, and that combination ensures that human groups have very pronounced impacts on their local physical and biological environment. We do not tread lightly on our world, and have not done so at least since the origins of farming and animal husbandry, and probably much longer (Dounias 2001; Barton et al. 2004): some foraging techniques like fire-stick farming have pronounced and deep impacts on the environment (Grayson 2001; Jones 1969). Second, the demographic, geographic, and ecological expansion of humans over the last 50,000 years ensures that humans have had these local impacts almost everywhere. We are a cosmopolitan species with cosmopolitan impacts. Third, humans, like many niche construction organisms, alter the environment of the next generation, not just the current crop of engineers. But, in contrast to most other species, our niche construction is not just cross-generation; it is cumulative. Generation N+1 inherits an altered world from generation N, they make further modifications, which are then inherited by generation N+2. They construct more shelters; fell more trees; modify watercourses; drive potential predators to local extinction; inadvertently create favourable conditions for pathogens by moving less frequently (Laland et al. 2000). Social and economic environments are modified and further modified too: trade connections with neighbours and their neighbours are established, stabilized, ramified (or move from coexistence to suspicion to hostility to permanent warfare).

Finally, developmental niche construction plays a unique role in human life. As originally developed, the theory of niche construction understood the environment as the selective environment. Agents modify their surrounds in ways that change the selection pressures that act on them: a burrowing animal is much less exposed to the weather; a beaver in its lodge is safe from many predators. But niche construction has developmental impacts too. Termite mounds and beaver complexes structure the environment in which the next generation develops. In modifying their own environment, many organisms also engineer the developmental environment of their offspring. Since the effects of genes are often sensitive to their context, these changes in the developmental environment affect the next generation's phenotypes. Thus, termites develop in a world built by and for termites. Likewise, human children grow up in a world profoundly modified by their parents and their parents' generation. In our species, developmental niche construction is of fundamental importance to learned behaviour. Explicit teaching is part of the developmental experience of human children (though there seems to be considerable cultural variation in the extent of such teaching). But much more importantly, human children learn by trial and error in a world enriched by informational resources provided by adults: toys, tools, stories, pets, and other domesticated animals; games; artefacts in various stages of construction, and much else (Derevenski 2000). Juvenile environments are enriched by adult activities and products, and this is part of the explanation of the power and pervasiveness of human social learning. Humans inherit ideas, techniques, prejudices, skills, norms, and customs from their parents and their parental generation, and the power and fidelity of such cultural learning depends on the ways human developmental environments are structured, as well as individual cognitive adaptations for learning and teaching (Sterelny, 2003).

With the exception of work on cultural inheritance and social learning, there are as yet few attempts to incorporate niche construction into the formal models of human behavioural ecology. But the niche construction perspective transforms both the questions and the explanatory toolkit of Darwinian archaeology. Tools, fire, and other forms of material culture are not just responses to selection pressures exerted by the environment; their use cumulatively modifies the environment in which agents act. Prey is depleted; predators become more wary. The physical environment becomes easier to move through and to navigate, as tracks and pathways become established by custom and use. Some resources are depleted, but others become more accessible; rockfaces and ochre sites become easier to reach and to use. More generally, because of the reciprocal and cumulative effects of humans on their world, humans must adapt to living in an ever-changing environment.

Niche construction theory, especially in relation to human evolution, remains work in progress. The conceptual realism of niche construction has yet to be yoked to the formal rigour of human behavioural ecology in ways that yield clearly testable hypotheses. That said, the general approach ought to be highly congenial to archaeology. It takes history seriously: the environment a culture finds itself in, and the options available to it, result in part from the history of interactions between culture and world. History matters, and sometimes individuals must adapt to the vagaries of history. The niche constructed by my ancestors may be subtly but importantly different from that constructed by yours.

The core idea of niche construction, this notion of an inherited world of ideas, norms, of material culture and changed environments, has been an implicit part of the intellectual milieu of archaeology for decades. Graham Clark and V. Gordon Childe (and others) were fully aware of the fact that humans significantly impact upon, and

transform, their environment. And the idea that these impacts are *inherited* is of course fundamental to what we mean by culture. Indeed, it is this very criticism of naïve evolutionary ideas that have forced those interested in human evolution to take seriously cultural inheritance, and the ideas of niche construction (Sterelny 2003). As a consequence, archaeology will be on the front line of research testing niche construction, for only archaeology has the historical depth and geographical spread to test these ideas against the full range of human experience. But even once we build in these notions of inheritance and history into Darwinian archaeology, it will still have limits.

The limits of Darwinian archaeology

Evolution by natural selection acts on populations, and only on populations with particular characteristics (Godfrey-Smith 2009). There must (obviously) be fitness differences within the population, and inheritance across its generations, and these conditions are not always met. But that is not all. So, for example, if a population is small and ephemeral, selective models are not likely to be helpful, for chance events are likely to dominate the group's history. This matters. The populations, the groups, the time-scales that archaeologists work with are typically quite fine-grained and small. Whilst we are quite keen to know the history of a particular region over the course of 1,000 years, an archaeologist dealing with an archaeological site is often confronted with the local history of a small group over a couple of hundred years. At this scale, small changes in the views and behaviours of an individual can matter a great deal. Inspiring leaders can change the sociopolitical world, and a small innovation by an individual can literally change the landscape.

The grain of analysis is also important to the utility of Darwinian models. Recent attempts to understand religion as the result of evolutionary processes are a clear case in point. We might, for instance, accept the notion that religious belief in supernatural agents is a by-product of human's capacity for detecting agency (Guthrie 1993; Andresen 2001). But that will not explain the differences between two different groups' attitudes, beliefs, and practices towards mountains, even if the belief that mountains are intelligent agents is common. One group may see mountains as benevolent protectors and ancestral homes, another, mountains as demonic abodes. Both groups might see mountains as intelligent agents in line with the evolutionary hypothesis. But that hypothesis predicts *nothing* of the two groups' quite distinctive behaviours. History, at the level of both the individual and the group, may well explain the differing attitudes to mountains of two groups. The commonalities between groups may be explained by Darwinian ideas. Likewise, the individual range of variation, the norm of reaction, might also be explained by Darwinian ideas. But that is not true of the idiosyncrasies of an individual or group, and these are often of interest to archaeologists and ethnographers. Darwinian archaeology reaches its limits where chance dominates pattern.

As noted previously, dual inheritance theory is in part an exploration of the limits of Darwinian natural selection. Dual inheritance theory acknowledges that cultures are a complex tapestry of interactions between Darwinian and non-Darwinian selective processes, and seeks to model those interactions. Moreover, dual inheritance theory emphasises the need to explore the local patterns of these interactions.

Culture's tangled bank

In the final paragraphs of Darwin's *Origin of Species*, Darwin talked of nature's tangled bank of organisms. Culture too is a tangled bank. Some of the products of culture have simple selected functions; they are adaptations to the cold; to the desert; to the local food sources. Much technology is present for simple functional reasons, and we would expect such technologies to respond rapidly to environmental change. However, other cultural phenomena will be more complex, present because of complex feedback loops between constructed environments and groups, between individuals and the society within which they find themselves. We should expect sometimes to find in cultures frozen accidents, locked into place as ideological inertia clamps down on innovation and variation (Sterelny 2007). A cultural innovation may be adaptive in two different cultural settings, but embraced by one group, and rejected by another as witchcraft. Human cultural worlds are complex and interconnected. To some extent, processual archaeology was right to see cultures as systems. Darwinian approaches to the archaeological record will often be fruitful, but they will need to be nuanced, and attuned to the historicity and the heterogeneity of human cultures, and the dynamism of human environments.

Our conclusion then is a recommendation to acknowledge cultures tangled bank: to be aware that there is no easy application of Darwinian ideas to understanding the human past. Decisions about whether a set of cultural products acts as a Darwinian population, and if it is, how selection acts on it, require case-by-case assessments. In each instance, we must show rather than assume that natural selection acts. However, if it does act, natural selection offers powerful tools for understanding the past. If not, then archaeology has many other explanatory tools available.

Suggested reading

We would strongly recommend Peter Godfrey-Smith's book *Darwinian Populations and Natural Selection* (2009) as a text for an up-to-date view on evolution and natural selection. Kevin Laland and Gillian Brown's *Sense and Nonsense: Evolutionary Perspectives on Human Behaviour* (2002). remains an accessible, readable, and thorough introduction to the application of Darwinian ideas to human behaviour and culture. Kim Sterelny's forthcoming book *The Fate of the Third Chimpanzee* should provide a good insight into the evolution of human learning strategies and human niche construction. While somewhat dated now, Herbert Maschner's edited collection *Darwinian Archaeologies* (1996). bears rereading in the light of the above recommendations, as does perhaps the one of the most systematic attempts to integrate archaeology and cultural evolution: Stephen Shennan's *Genes, Memes and Human Cultures* (2002).

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