

Evolutionary Archaeology
Invited Review:

**What Can Archaeology Do With
Boyd and Richerson's Cultural
Evolutionary Program?**

By Benjamin Marwick

Australian National University

Not By Genes Alone: How Culture Transformed Human Evolution (2005) PETER J. RICHERSON and ROBERT BOYD. University of Chicago Press, Chicago. xi + 342 pages, 3 halftones, 5 line drawings. \$30.00 ISBN 0-226-71284-2

In a famous letter, the economist Alfred Marshall outlines a method for economic theorising: "(1) Use mathematics as shorthand language, rather than as an engine of inquiry (2) Keep to them till you have done (3) Translate into English (4) Then illustrate by examples that are important in real life (5) Burn the mathematics (6) If you cannot succeed in 4 then burn 3." (Pigou 1925). If Marshall's method is relevant to the way Boyd and Richerson work, then their new book is evidence that their theorising has reached an advanced stage. In their new book *Not by Genes Alone* (hereinafter, NBGA) there are none of the dense maths that distinguished their influential book *Culture and the Evolutionary Process* (1985), instead there are numerous examples drawn from the human sciences. The main point of this new book is to show that Darwinian evolutionary theory and methods are essential and productive tools for the analysis of human culture. This is a theme that Boyd and Richerson have been promoting since the late 1970s, but NBGA presents a more accessible account of their cultural evolutionary program and outlines a manifesto for future research. The book is aimed at readers in social science and humanities departments, with no graphs, only a single equation buried in the endnotes, axiom-like chapter headings, and case studies drawn from across the human sciences. The publication of this new synthesis of their ideas provides a good opportunity to review the main arguments of Boyd and Richerson's work as described in NBGA and evaluate the impact their program has had on archaeological research.

In their invitation to the social sciences to see what evolutionary biology has to offer, Boyd and Richerson build the conceptual framework of NBGA around two ideas that are the core of their program. The first idea is population

thinking. Amongst biologists this is a fundamental ontology that has made all the difference since its introduction by Darwin. Before Darwin's publications, most biologists considered a species as an immutable, discrete, Aristotelian kind and variation as illusory. After Darwin, this idea was replaced with the view that species are populations of individuals showing continuous variation and individual variation within a species is the result of ongoing processes of mutation.

This shift from essentialist to materialist thinking has thoroughly permeated biology and Boyd and Richerson argue that a similar shift would be advantageous for the social sciences. Their key point is that within and between cultural groups there is a continuous range of variation in the cultural information in any individual's head. Culture is defined as 'any kind of mental state, conscious or not, that is acquired or modified by social learning and affects behaviour' (p. 5). This definition of culture distances Boyd and Richerson from sociobiological approaches to cultural evolution that tend to define culture as the expression of naturally selected adaptive genes (Ehrlich and Feldman 2003). Thinking about the population properties of culture is not unique to Boyd and Richerson and is also the foundation for a variety of models of evolution and human behaviour (Bryant 2004). The uniqueness of Boyd and Richerson's program comes from the second major idea: that of the many forces shaping cultural evolution, some of the most powerful are those arising from the psychology of individuals that makes them more likely to adopt some variants of culture than others.

CULTURAL TRANSMISSION BIASES AND
ARCHAEOLOGICAL APPLICATIONS

These forces occur during the social learning of culture and are described as cultural transmission biases, occurring when people choose (consciously or otherwise) to adopt certain cultural variants rather than others. In NBGA Boyd and Richerson describe three kinds of transmission biases using examples from previously published social science literature. The first bias is the 'content-based bias' that occurs when individuals are more likely to learn, remember, and teach some cultural variant because of its content. Content-based bias can

result from (not necessarily conscious) calculations of costs and benefits associated with cultural variants or when the content of the variant more easily lends itself to learning, memorisation, and teaching than alternative variants. The second bias is 'frequency-based bias', occurring when the commonness or rarity of a cultural variant is the criteria determining transmission. When the common variant is more frequently transmitted this bias is called 'conformist bias'. The third bias is 'model-based bias' that occurs when a variant is transmitted because of its association with a suite of other attributes associated with individuals exhibiting the variant. Finally, there is 'guided variation', where individuals acquire new cultural variants by copying existing behaviours and then modifying them through trial and error to suit their own needs.

These concepts were first presented by Boyd and Richerson in the 1980s and are often invoked in archaeological studies but less frequently used to systematically investigate archaeological problems. Good examples of a thorough employment of these concepts are found in the work of Bettinger and Eerkens (1997; 1999) who use metric analyses of late Holocene stone artefact assemblages from the Great Basin of western North America to explore the consequences of different cultural evolutionary processes. In their 1997 study they analyse a large sample of projectile points ($n = 5285$) to test predictions about the effects of different types of cultural transmission on metric variability. They expect that guided variation and content-based bias will be important during times of low population densities and technological complexity because competing variants are easily compared by field testing and individual experience. When the population grows and/or technology becomes more complex they expect frequency-based and model-based biases to be more important because individual field testing of variants is inefficient compared to relying on social transmission of pre-tested variants. These expectations allow them to hypothesize that complex point shapes will have less metric variation than simple forms, that arrowheads will be less variable than dart points and that long-lived forms will be more variable than briefly appearing forms. These expectations receive only equivocal support from the data. As predicted, complex point

forms show less metric variation than simple forms, and arrowheads show less variation than dart points. However, 81% of metric variation is strongly correlated with artefact size ($r = 0.899$), meaning that differences in types of cultural transmission have only a small effect. Inspired by Bettinger and Eerkens, Shott (1997) undertook a similar test of these social transmission models using metric attributes of stone points from late Holocene contexts of the North American Midwest and found that differences in cultural transmission have an even smaller effect on lithic variation than observed by Bettinger and Eerkens.

More encouraging results come from Bettinger and Eerkens' (1999) study of changes in metric variables of stone points during the introduction of bow and arrow technology to eastern California and central Nevada at around AD 300–600. Using an approach similar to their earlier study, they equate guided transmission with high metric variation and low correlation between different metric attributes (such as mass and basal width). Lithic assemblages with metric variables that are less variable and more highly correlated are equated with model-based bias. Their analysis shows that assemblages from eastern California have poor correlations of basal width and mass, suggesting that bow-and-arrow technology was probably introduced and spread by guided variation. Conversely, in central Nevada, the new technology was probably introduced and maintained by indirect bias because the metric attributes are strongly correlated. Bettinger and Eerkens interpret this data to mean that eastern Californian groups acquired the bow and arrow from distant and unfamiliar neighbours, and with limited contact they had to develop and customise the bow and arrow technology largely by trial and error. The opposite seems to be true for central Nevada where the appearance of bow and arrows was probably a result of faithful copying, suggesting closer social contacts with the donor group. They further conclude that these differences in social transmission indicate substantial differences in social organisation and hunting behaviours in the two regions.

Despite their innovative statistical approaches and the success of their second study, Bettinger and Eerkens' method has not been widely adopted in other lithic studies, nor is it cited in

NBGA. This is probably because stone artefact assemblages in general (especially non-point types) are somewhat limited in shape and size variation, as well as limited in the potential for decoration that is independent of the artefact's physical performance. This is because stone artefact production involves a one-way and continuous decrease in size and often substantial changes in morphology over the life of the artefact by removal of mass from the original piece (Shott 2005). More often, evolutionary studies of stone artefacts follow the evolutionary ecology approach (also known as human behavioural ecology) that provides models to associate technological attributes of lithics with behaviours relating to individual fitness in given contexts (e.g., Bamforth and Bleed 1997; Bousman 2005; Kuhn 2004). This approach interprets assemblage change as evidence of adaptive variation in behaviours responding to changing social and ecological conditions. It is based on the assumption that natural selection has designed individuals to respond to changing conditions in a way that yields the greatest possible benefit for the individual's survival (Boone and Smith 1998). This is an application of evolutionary thinking that is distinct from Boyd and Richerson's program because evolutionary ecology generally attributes archaeologically observed changes in behaviour to phenotypic plasticity (O'Brien and Lyman 2002) rather than the ongoing selection processes that interest Boyd and Richerson.

We might expect that Boyd and Richerson's approach would have greater influence in archaeological studies of artefacts that preserve information about learning and information transmission and are relatively unaffected by loss of mass and major changes in morphology during their use-lives. These kinds of artefacts can be made with additive technologies such as ceramic, metal, and cloth production where variation unrelated to the artefact's physical performance is possible through the use of moulds, patterns, and decorations. Ethnoarchaeological studies of ceramic production suggest that successful transmission of ceramic traditions requires a long-lasting relationship between teachers and learners (Shennan and Steele 1999), providing an ideal context to examine the effects of transmission biases. Indeed, studies of cultural evolutionary processes using

ceramic assemblages have been much more successful than the lithic studies. Although not explicitly framed in Boyd and Richerson's terms, Neiman's (1995) sophisticated and influential study of variations in decorations on cooking pots across 35 Hopewellian assemblages in Illinois identified changes in the levels of inter-group social transmission that relate to changes in the level of long-term residential movement of potters between groups. Neiman's study drew on a specifically archaeological adaptation of evolutionary theory proposed by Dunnell (1978; 1980) that is quite independent of Boyd and Richerson's program. Despite this different intellectual heritage, Neiman's work is significant because his approach is basically similar to Boyd and Richerson, and his methods have been used by others who have more closely followed Boyd and Richerson's scheme for understanding cultural evolution and transmission.

Neiman's work is important because he showed, like Boyd and Richerson, how methods derived from population genetics can be used to generate expectations about human behaviour. Neiman used biological models describing neutral variation in genetic populations to explain stylistic diversity in archaeological assemblages. First, he builds mathematical models to describe the effects of population size, drift, and innovation rates on within- and inter-assemblage diversity. Drift is defined as 'sampling error' that occurs during social transmission and reduces variation, while innovation is defined as a constant and selectively neutral source of variation that appears during social transmission. In brief, his models show that assemblage diversity is proportional to assemblage and population size, that assemblage diversity will increase during times of increased population and increased between-group interaction, and that under conditions of drift and neutral variation, within-assemblage variation is inversely proportional to between-assemblage variation. Second, Neiman analyses the diversity of the 26 different types of lip exterior decoration of ceramic cooking pots in 35 assemblages. Following Dunnell, lip decoration is identified as an attribute that is 'stylistic' (attributes with variants that have equal value to an individual's reproductive fitness and change by drift, typically attributes unrelated to an artefact's physical performance, such as decoration) rather than 'functional' (those that are

under selection because they relate directly to the survival and reproduction of an individual, such as performance related attributes). This distinction between function and style separates Neiman from Boyd and Richerson in two important ways. Firstly, Neiman does not consider learning and social transmission biases to be relevant selective forces (Lipo et al. 1997); and secondly, he does not allow for the possibility that style and function may have complex co-evolutionary relationships. For example, stylistic attributes may be signalling systems that influence an individual's reproductive success (Bird and Smith 2005). Neiman's third step is to group the assemblages into seven chronological units based on sherd thickness, which decreases over time. He then calculates the observed diversity values of lip types in each assemblage for each time period from the archaeological data and calculates expected values using the mathematical models.

The results show that within-assemblage diversity is low during the Early Woodland Period (before 200 BC), increasing to a peak in the Middle Woodland Period (200 BC–AD 400) and declining again in the Late Woodland (AD 400–800). Conversely, just as predicted, between-assemblage diversity is high during the Early Woodland, then becomes low, and is finally high again in the Late Woodland. The similarity between the observed results and the modelled results indicates that the neutral model accurately describes the archaeological evidence. Following his models, Neiman interprets this as evidence that the highest levels of social interaction were occurring during the Middle Woodland period and the lowest levels occurring during the Late Woodland period. Further, Neiman suggests that high levels of social interaction during the Middle Woodland relates to an increase in long-term residential movement of potters, a conclusion supported by evidence of gift exchange relations in the Middle Woodland that then ceased in the Late Woodland. Given the elegance, robustness, and utility of Neiman's study, it is surprising his method has not become widespread. Kohler et al. (2004) suggest the dogmatic separation of function and style by Neiman may have discouraged others who do not see such a clear distinction.

There are two ceramic studies that have been

inspired by Neiman's work and both reject the separation of functional and stylistic attributes as well as Neiman's conclusions that variation in diversity results only from innovation and drift. Instead, they adopt Boyd and Richerson's model of social transmission as a source of the variation that Neiman's neutral model cannot explain. Shennan and Wilkinson (2001) analysed changing patterns in the frequency of 35 different types of decorative bands on the bodies of ceramic vessels from two settlements of the early Neolithic *Linienbandkeramik* (5300 to 4850 cal BC) in western Germany. They use Neiman's model to generate expected and observed diversity values from the archaeological data and find that the expected values of inter- and between-assemblage diversity do not match the archaeological observations, so they reject the neutral model as the source of variation in LBK ceramics. In the early LBK phases the diversity of ceramic assemblage decoration was less than would be expected under the neutral model, while in the later phases it was greater. To explain this they model ceramic variation as a cultural 'quasi-species' subject to mutation and selection. They propose that during early LBK phases assemblage diversity was limited by conformist bias resulting in the rejection of novelty. The increased diversity in the later phases was caused by a pro-novelty negative frequency-dependent bias (Bentley and Shennan 2003). They explain that this increase in novel decorations was an assertion of identities during increasing population densities, suggesting a decline in inter-site interaction. Support for this interpretation comes from a cladistic analysis of relationships between a larger sample of sites in the same region showing that the diversities of late phase LBK assemblages are more closely related to their ancestral assemblages than interaction between neighbouring sites (Collard and Shennan 2000). Despite the elegance of this study and its success in using transmission biases to explain archaeological data in behavioural terms, it only features in a footnote in NBGA, perhaps due to Boyd and Richerson's preference to use more contemporary examples from political science, linguistics, sociology, and economics.

Another instructive archaeological application of social transmission models is provided by Kohler et al. (2004) who examine changes in ceramic diversity to explore the effects of

increasing settlement size and aggregation in the pre-hispanic (AD 1175-1315) Puebloan southwest US. They measured changes in the diversity of 83 different styles of black-on-white wares from eleven sites ranging in size from six to 65 rooms. Neiman's methods were used to examine the neutral model's predictions that the diversity of stylistic variants should increase as population size increased from hamlets to villages. Like Shennan and Wilkinson, they find that the neutral model does not explain the observed diversity. Diversity is much less than the model predicts and Kohler et al. reject the possibility of increased specialization of ceramic production (fewer people making more vessels) because there is no corresponding reduction in coefficients of variation of metric variables. Instead they suggest that the low ceramic design diversity should be explained by differences in the social transmission of designs. They consider the possibility of model-based bias, where potters would actively imitate the products of one who was particularly prestigious, but they reject it because the relative homogeneity of architecture and other materials at the sites does not suggest greatly differing degrees of prestige. Kohler et al. conclude that conformist bias is the most significant force, where an individual selects the most common model to imitate. They view the conformity in ceramic design in the later phases as indicative of high levels of within-group cooperation and the punishment of defectors by ostracism. This conformity is argued to be an adaptation to increasing external competitive pressures (for access to the best arable land, hunting territories, lithic raw materials, and probably defence) as population densities increase.

These examples show how archaeologists have adapted the explanatory potential of Boyd and Richerson's cultural evolutionary forces. Applications to lithic studies have met with varying success but the ceramic studies have been very successful, largely due to Neiman's innovative modelling (although conceived for different purposes) and the intrinsically more plastic and variable nature of ceramics compared to stone. Given that social transmission biases have been shown to be important in prehistoric contexts, we might ask when these forces first became important in human societies. Unlike almost every other author who has written about the

evolution of culture, Boyd and Richerson prefer not to equate transmission bias with selection. This is a fine point, but an important departure from cultural evolutionary models like memetics (Blackmore 2000) and cultural virus theory (Cullen 2000). These approaches generally follow the principles of biological Darwinian evolution of descent with variation, equating cultural variants with self-replicating entities such as genes or viruses that are directly subject to selection. Boyd and Richerson distance themselves from this kind of analogizing by following Sperber's (1996) idea of non-replicating, non-particulate cultural variants that are very different from genes. In Boyd and Richerson's program transmission biases are unique evolutionary forces for selective retention of cultural variants that originate from adaptations generated by natural selection operating on genetic differences between individuals. The adaptive advantage in these biases is that they often allow humans to quickly and reliably acquire adaptive cultural variants without costly and difficult evaluations of the advantages and disadvantages of different variants. Although the adaptive value of culture is generally intuitive, the specific reasons offered by Boyd and Richerson for why these biases are adaptive have been criticised for understating the costs of biased transmission (Sterelny 2006).

THE ARCHAEOLOGY OF THE EVOLUTION OF TRANSMISSION BIASES

Criticisms aside (it is only modelling after all), the ultimate derivation of the transmission biases from natural selection on genes is the key to the dual inheritance programme of Boyd and Richerson. This program holds that humans, unlike other animals, inherit behaviour through two routes: genes and culture. In fact, the separation of humans and animals is not as great as Boyd and Richerson suggest, with evidence for cultural groups, social learning, and even conformist bias in primate populations (Whiten, Horner, and de Waal 2005; van Schaik et al. 2003). Similarly, Boyd and Richerson's evolutionary narrative in NBGA has an unrealistically sharp break with primates and early *Homo* on one side and modern humans on the other. This distancing of *Homo sapiens* from extant relations and extinct ancestors does not agree with the available evidence. Their gloss of *Homo habilis*

does not discuss significant evidence of cognitive abilities that distinguish late Pliocene hominids from primates, such as the diversity of technical behaviours in Pliocene stone artefact assemblages (Roche et al. 1999; de la Torre et al. 2003) or the patterns of raw material movement that involve much further transfers than demonstrated by wild primates and suggest greater planning depth (Marwick 2003). Middle Pleistocene hominids are similarly abandoned as 'only a bit brainier than the bipedal apes that preceded them' (p. 141). Boyd and Richerson more accurately and parsimoniously attribute the long-term and wide-area similarities of Acheulean handaxes as a result more of genetically transmitted psychology and raw material constraints than cultural transmission (McPherron 2000) although they omit any discussion of the social, cognitive, and behavioural significance of the geographic dispersal of Middle Pleistocene hominids out of Africa (Roebroeks 2001) or the life history markers of these hominids that indicate a social organisation more similar to humans than primates (Leigh 2006; Connell, Hawkes, and Blurton Jones 1999; Wrangham et al. 1999). For Boyd and Richerson, most of the early and middle Pleistocene is little more than a time of natural selection for larger brain sizes as an adaptation to the highly variable Pleistocene climates. Using comparative studies they point out that larger brains are strongly associated with increased capacity for behavioural flexibility and social learning, suggesting that with an increasingly bigger brain early *Homo* could discover and learn novel behaviours that are adaptive to rapidly changing climates faster than genetic selection could supply them.

They are on firmer ground in their discussion of the gradual appearance of signs of modern humans during the African Middle Stone Age. They note that archaeological evidence of cultural modernity, or cumulative cultural adaptation in their words, emerges from a thin spread of evidence over a large area and long time period during the Middle Stone Age (d'Errico et al. 2003). For Boyd and Richerson, this is the time when natural selection for gradual increases in brain size finally culminates in the psychological machinery for social transmission biases. Disappointingly, their discussion of the archaeological evidence for language evolution is overly-con-

servative and dated. There is also no mention of the impressive efforts made by linguists to understand the evolution of language (e.g., Jackendoff 2002), especially the important argument that language itself may be a distinctive evolutionary system similar to biological and cultural systems (Brighton, Smith, and Kirby 2005). Mention of other selection-based evolutionary systems, such as the immune system (Hull, Langman, and Glenn 2001) and neurons (Edelman 1993), might make Boyd and Richerson's idea of cultural evolution appear more plausible to skeptics who regard evolutionary processes as exclusive to genetics.

After the emergence of cumulative cultural adaptations in the African Middle Stone Age, Boyd and Richerson's theoretical and mathematical modelling suggests that group selection of cultural variations becomes possible and results in cooperation, altruism, and punishment in small groups. From these group-selected qualities follow the existence of ethnolinguistic tribal institutions that facilitated periodic aggregation of small groups for communal activities. Although there is good archaeological evidence for this, especially in the later Pleistocene (Conkey 1980; Vanhaeren and d'Errico 2006), Boyd and Richerson prefer to focus on ethnographic studies in NBGA.

After the emergence of cumulative culture in the African Middle Stone Age, the next big thing in Boyd and Richerson's account of human history is the Holocene, when many human groups gave up the Pleistocene hunter-gatherer way of life to pursue domestication and organise themselves into more diverse, complex and larger social groups. In NBGA they address some of these changes in an engaging chapter on cultural behaviours that reduce our genetic fitness, or cultural maladaptations, which they view as inevitable byproducts of cumulative cultural adaptation. In the Pleistocene, natural selection shaped our psychology so that it uses predictive cues—the transmission biases—as short-cuts to quickly generate adaptive behaviour, but in larger groups these biases, especially conformist and model-based biases, result in the spread of behaviour that can reduce our genetic fitness. As soon as an individual's behaviour is influenced by cultural variants transmitted by non-kin then non-adaptive cultural variants can spread. This focus on social learning separates

Boyd and Richerson from the most serious competing explanation for maladaptations, the evolutionary psychology paradigm. Evolutionary psychologists argue that culture derives from genetically-designed neural circuits selected to produce adaptive behaviours during Pleistocene conditions (Barkow, Cosmides, and Tooby 1992). According to the evolutionary psychology paradigm, maladaptations result when these innate brain structures produce behaviours in social and ecological situations that differ from the Pleistocene contexts where they were forged. In their view, cooperation and altruism occurs because people erroneously believe they are dealing with kin and basic behaviours related to kin-selection are activated.

THE ARCHAEOLOGY OF CULTURAL GROUP SELECTION

Group selection is another concept that separates Boyd and Richerson from evolutionary psychologists who generally argue that selection only occurs at the level of an individual's genes. Group selection has important implications for cultural evolution with Boyd and Richerson suggesting that when individuals migrate into a new group they can change their behaviour to conform to new norms, thus reducing within-group variance in norms, and maintaining between-group variance. The integrity of the cultural group is preserved because immigrants will preferentially adopt common practices, but the genetic integrity of the group is diminished because offspring acquire their genes from their parents, not from the group. This allows for the proliferation of distinctive cultural groups with long-term, stable cultural traditions. There are a number of empirical studies that apply phylogenetic analyses to anthropological and archaeological data to demonstrate this effect of group selection (Collard, Shennan, and Tehrani 2006). It is surprising that none of these studies are referred to in NBGA, given Boyd and Richerson's commitment to using methods borrowed from biological sciences and the increasing significance of phylogenetic methods in the human sciences (Mace, Holden, and Shennan 2005; Lipo et al. 2005).

These phylogenetic studies focus on the debate about the relative importance of phylogenesis (where cultural similarities and differences among human populations are primarily

the result of a combination of within-group information transmission and branching away from ancestral populations) and ethnogenesis (where cultural change occurs through the borrowing and blending of variants among contemporaneous populations) in cultural evolution. Although the studies are not explicitly designed to test Boyd and Richerson's group selection concept, they provide good evidence of cultural group integrity. They follow cladistic methods used in biology and test a null model where new cultural variants arise from the bifurcation of existing ones and a tree diagram (cladogram) is drawn to show the ancestries of a number of variants. Statistical analysis of the relationships shown in the cladogram are used to test the null model by showing the importance of similarities resulting from shared ancestry (homologies) or those due to mechanisms other than shared ancestry (homoplasies). Tehrani and Collard (2002) used this method to examine 90 attributes on 60 woven artefacts produced between the 18th and 20th centuries by five groups of Turkmen from Turkmenistan, northern Iran, and northern Afghanistan. A sub-sample was divided into two time periods based on the use of natural or artificial dyes to identify possible changes in the Turkmen material cultural evolution associated with the Russian colonisation of Central Asia in the 19th century. Tehrani and Collard (2002) aimed to determine if phylogenesis or ethnogenesis dominated the evolution of Turkmen textile designs prior to the Turkmen's defeat by Tsarist Russia, and to see if the contributions of phylogenesis and ethnogenesis change following the Turkmen's pacification and settlement by the Russian colonial authorities. Their results show that prior to Russian colonisation about 70% of the similarities among the assemblages are homologous and approximately 30% are homoplastic, indicating that cultural phylogenesis is more important in cultural evolution than ethnogenesis. After Russian colonisation ethnogenesis becomes about 10% more important (about 60% of the interassemblage resemblances are homologous and about 40% are homoplastic) suggesting an increase in blending of designs and innovation, consistent with historical accounts of increased sedentism and increased production for market sale rather than domestic use.

Tehrani and Collard's study is a good example

of how phylogenetic methods demonstrate the integrity of group-level cultural phenomena. This might be expected, with the complexity of carpet making and the time taken to learn the techniques limiting the potential for diffusion, but phylogenetic analysis of simpler cultural materials also shows the importance of group selection. Collard and Shennan (2000) analysed pottery data from seven early Neolithic settlements in western Germany. Results from four settlements that were continuously occupied throughout the ten-phase period indicated that pottery decorations were generated both by phylogenesis and by ethnogenesis. On the other hand, the three assemblages that were newly founded in the ten-phase period derive from a single ancestral assemblage, suggesting phylogenesis was most important. There is also evidence that phylogenesis is not always as important, or that its signals have been eroded by different rates of innovation (Jordan and Shennan 2003), but a review of a large number of quantitative studies by Collard et al. (2006) shows that in most cases phylogenesis is more than, or at least as important as, ethnogenesis.

CONCLUSIONS

Boyd and Richerson are not alone in the field of gene-culture co-evolution (Durham 1991; Cavalli-Sforza and Feldman 1981), but are probably the most prolific and influential. Their central thesis is that socially transmitted culture is crucial for a full understanding of human behaviour, while at the same time human culture has a biological basis and can be considered an evolutionary system in its own right. This review has outlined the most important arguments presented in NBGA and discussed a few examples of how these arguments interact with archaeological research. The contents of NBGA go beyond the scope of archaeological inquiry and some of these other topics have been discussed by Mameli (in press) and Machery (2005). This review has shown that Boyd and Richerson have produced explanatory frameworks that have helped generate substantial innovation in archaeological methods and robust anthropological explanations of past human behaviour. Boyd and Richerson have also suggested narratives of human evolution that are archaeologically testable but require revision to correct their underestimation of pri-

mate and early hominid abilities. Using the example of group selection and the debate about phylogenesis versus ethnogenesis, this review has also shown that archaeology has the potential to provide real-world tests of Boyd and Richerson's models. This lack of purpose-built real-world tests and examples is a major weakness in Boyd and Richerson's work, and evolutionary approaches to the human sciences generally, which have often been accused of generating more programmatic statements than useful results (Bamforth 2003; Shott 1997). NBGA goes some way towards employing case studies from anthropology, history, linguistics, and psychology in the service of cultural evolutionary models but lacks the empirical density and persuasive rhetorical force of popular writing in the biological sciences (e.g., Jones 1999; Ridley 2003). This is probably because biology has been so much more successful than anthropology and many related fields of the social sciences over the past 150 years. But why has this been the case?

Mesoudi et al. (2006) suggest two answers to this problem. First, biologists typically are more willing than social scientists to simplify complex systems down to workable assumptions and models that ultimately form the basis of sophisticated explanations. Complex problems in the social sciences remain intractable because researchers object that human culture is too complex to apply simplifying assumptions and methods. Second, biology and its diverse sub-disciplines are united by the theory of evolution but the social sciences have no such synthesizing framework showing how cultural anthropology, archaeology, psychology, economics, sociology, and history are studying complementary aspects of the same problems. Mesoudi et al. (2004; 2006) argue that cultural evolution has key Darwinian properties and suggest that it has the potential to synthesize the social sciences as it has the natural sciences. As outlined in NBGA, Boyd and Richerson's program is an essential contribution towards this evolutionary synthesis of the human sciences. Boyd and Richerson's work also points us in two important directions where progress is vital before a golden age of evolutionary synthesis can emerge.

The first direction is experimental research to show how individual-level mechanisms for acquiring behaviours contribute to phenomena

at the population level. Microevolutionary laboratory studies have been the foundation of biological evolution because simple versions of complex systems can be controlled and examined in ways that are impossible in field conditions. Laboratory studies of microsocieties are the equivalent tools for examining many aspects of cultural transmission under controlled conditions. Baum et al. (2004) have shown how traditions can appear and evolve in microsocieties of four people under controlled conditions. More of these studies are needed to test the effects of the different transmission biases identified by Boyd and Richerson as well as theorise the effects of power, conflict, and manipulation in social learning contexts. Most cultural evolutionary processes observed in the archaeological record are just long-term patterns of behaviour by multiple agents (Flannery 1999), so a better understanding of agent-level processes will improve our understanding of cultural evolution. The second direction where progress is necessary is about how the brain works. Understanding the neural basis of learning, memory, and transmission is important for knowing how reliably Boyd and Richerson's claims about learning and transmission bias can be generalised. This is obviously a field distant from most archaeologists and is still a long way from producing useful results (McGaugh 2000), but will reveal the mechanics of learning and information storage and hopefully help resolve problems about how cultural variants are preserved and replicated.

However, archaeology can continue to test the explanatory power of cultural evolutionary theory without microevolutionary laboratory studies and brain scans just as Darwin managed without molecular genetics and game theory. In fact, even the classical definition of the gene as a discrete unit of vertical inheritance that the modern evolutionary synthesis was founded upon is now old-fashioned. Pearson (2006) describes studies revealing complex extragenomic and horizontal modes of genetic inheritance and Mameli (2004) presents a lengthy catalogue of evidence for nongenetic selection and inheritance in many species. This suggests that critiques of analogies between cultural and genetic evolution need to be revised and the two transmission systems, by their diversity and complexity, may have more in common than previ-

ously suspected. In NBSGA Boyd and Richerson confess that their work is similarly incomplete and in need of revision. This revision will only occur with continued empirical testing and some of this can be done by archaeologists.

To sum up, this new book is an accessible introduction to Boyd and Richerson's program of cultural evolution and is recommended to those interested in evolutionary approaches in the human sciences. They do more than just muddy the waters of the human sciences to declare them deep; they offer a method to find more interesting and productive shores. □

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