Evolutionary Explanation and the Record of Interest: Using Evolutionary Archaeology and Dual-Inheritance Theory to Explain the Archaeological Record

Ethan E. Cochrane

UCL Institute of Archaeology
31-34 Gordon Square
London WC1H 0PY

and

AHRC Centre for the Evolution of Cultural Diversity

to appear in 'Pattern and Process in Cultural Evolution' edited by Stephen Shennan
University of California Press

INTRODUCTION

In the first part of last century anthropologists and archaeologists such as Kroeber, Childe, and others suggested that in some instances material culture similarities in space and time could be explained by the passing of information between individuals. The kernel of this simple idea—people copy those around them—was quantitatively elaborated by scholars working in North America and Europe (Lyman and O'Brien 2003, Shennan 2000). Americanist archaeologists and ethnologists noted that when the material culture record was described in a particular manner, cultural trait frequencies approximated normal or unimodal distributions. Kroeber (1919:257), for example, revealed the "underlying pulsation in the width of civilized women's skirts, which is symmetrical and extends in its up and down beat over full century," while Nelson (1916:167) attributed the "normal frequency curve" exhibited by a pottery type across superposed excavation units to reflect a style that "came slowly into vogue, attained a maximum and began a gradual decline" within a long-resident population. These expectations for the temporal distribution of transmitted (also called mimicked, borrowed, or diffused) traits were similarly applied to the spatial dimension of cultural transmission (e.g., Ford 1952).

Several recent archaeological studies have developed these culture historical generalisations into a more robust theoretical framework (e.g., Lipo et al. 1997, Teltser 1995, Tschauner 1994). This framework is based on generalising evolutionary theory beyond its original biological purview, so that artefactual variation is *conceptually* similar to phenotypic variation and is a product of cultural transmission, distinct from biological transmission (Leonard and Jones 1987, O'Brien and Lyman 2002, *contra* Collard et al. 2007). Scholars working in the so-called evolutionary archaeology tradition have long focused on the problem of generating relevant descriptions of the archaeological record using classifications that define homologous and analogous similarities (e.g., Allen 1996, Cochrane 2002a, Lipo 2001, Meltzer 1981, O'Brien et al. 2002), and employing linked explanatory processes such as cultural transmission, drift, and selection for the differential persistence of artefact types.

Most research, however, using evolutionary theory to explain human behaviour and material culture has not developed from this Americanist culture historical base. Instead, many anthropologists and archaeologists (e.g., Bettinger and Eerkens 1999, Kohler et al. 2004, MacDonald 1998, Mc Elreath et al. 2003, Smith and Winterhalder 1992, Soltis et al. 1995) pursuing evolutionary explanations have focused on the complex cultural transmission patterns predicted by studies derived from population genetic-based models (e.g., Boyd and Richerson 1985), behavioural ecology (e.g., Krebs and Davies 1993), and social learning frameworks. The empirical expectations for cultural trait distributions in particular scenarios are then used to explain portions of the behavioural and material culture records. Henrich (2004), for example, constructed a mathematical model to compare the distributions of complex and simple skills over time in a finite population of cultural transmitters. Applying this model to the archaeological and ethnohistorical records of Tasmania, he argued that the loss of complex technologies over time resulted from a sudden decrease in effective population size and the difficulty of transmitting complex skills (cf. Read 2006). Like Henrich’s analysis, most contemporary use of cultural transmission is closely related to the seminal work of Boyd and Richerson (1985) and Cavalli-Sforza and Feldman (1981). While the explanatory frameworks used in this research tradition, known as dual-inheritance theory (also gene-culture co-evolution), do not share the same Americanist culture historical origins as much of evolutionary archaeology, both programs are used to explain archaeological variation as a result of cultural transmission and related evolutionary processes. Of course categorising evolutionary approaches in archaeology as two hermetically separated traditions is somewhat an overstatement as a few scholars have recently attempted to combine the two (e.g., Eerkens and Lipo 2005, Shennan 2003).

Here I explore some of the consequences of explaining archaeological variation using either dual-inheritance theory or evolutionary archaeology. For instance, the dual-inheritance framework is largely built to explain observable or potentially observable behaviour, not the archaeological record. Thus some dual-inheritance observational units, for example costly-punishment behaviour, may not be unambiguously applicable to the archaeological record (cf. Dunnell 1995:39-40). And for any scientific explanatory theory to be useful, relevant observational categories must be clearly applicable to the empirical record of interest (Willer and Willer 1973). This of course does not mean the architects of the dual-inheritance framework have not done their work. The responsibility for constructing a dynamically and empirically sufficient theory to explain the archaeological record lies with those who try to explain it.

To explore the relationship between theory and the empirical record, the next section compares the explanatory framework and empirical evidence of two well-established evolutionary sciences: palaeontology and neontological evolutionary biology. This comparison parallels that between dual-inheritance theory and the framework of evolutionary archaeology (see also Mesoudi et al. 2006). The subsequent section suggests some of the principal elements of both dual-inheritance and evolutionary archaeology approaches that should be necessary components of a scientific evolutionary framework built to explain the archaeological record. These ideas are demonstrated by applying the framework to the archaeological record of ceramic change in the south Pacific.

EVOLUTIONARY THEORY APPLIED TO THE "FOSSIL" AND BEHAVIOURAL RECORDS

Grantham (2004) has recently compared palaeontology and neontological evolutionary biology (i.e., the evolutionary study of living organisms, hereafter evolutionary biology) in a way that highlights a set of similar, but not identical, contrasts between the dual-inheritance and evolutionary archaeology frameworks. Grantham notes that both palaeontology and evolutionary biology are grounded in the theory of natural selection; practitioners in both are interested in explaining organic diversity; and they share a common technique, cladistics. Palaeontologists apply cladistics to the analysis of morphological characters, while those studying living populations can examine genetic characters in addition to morphologies. Grantham (2004:690) compares palaeontology and evolutionary biology by noting focus of study (i.e., empirical record), temporal perspective, theoretical concepts, methods, and data (Table 1).

Grantham does not compare the two disciplines by the classification units they use. Evolutionary biologists generally use a biological (i.e., reproductive) species concept (largely attributed to Mayr [see O'Brien and Lyman 2000:200-207]) to place organisms into species-groups. Palaeontologists, working with a different empirical record and not observing the reproductive behaviour of organisms must arrange organisms using different criteria, relying mostly on morphology and spatio-temporal distribution (Eldredge and Gould 1972, Gould and Eldredge 1977, Simpson 1943). Regardless of the differing theoretical ramifications of biological and palaeontological species concepts—punctuated equilibrium and the reality of species are two examples—O'Brien and Lyman (2000:43) note a distinction of importance for classification issues: "What appears to work well for an ecologist, for example, whose specimens are living organisms, does not work particularly well for a paleobiologist, whose subject matter for the most part consists of preserved hard parts of long-dead organisms." This distinction also pertains to evolutionary explanations of human cultural variation using either the behavioural or archaeological records.

We can compare the structure of dual-inheritance explanations of human cultural variation to the framework of evolutionary archaeology using Grantham's system. Indeed, for several of Grantham's comparisons we can simply change the column headings to dual-inheritance theory and evolutionary archaeology (Table 2). The focus of study or record that dual-inheritance theory was originally built to explain is observations of human behaviour (e.g., Boyd and Richerson 1985: chapter 3). For evolutionary archaeology the empirical record to explain consists of artefacts and their temporal and spatial variation. This point bears further discussion.

The focus on artefacts does not mean evolutionary archaeologists think behaviour is unimportant. On the contrary, the archaeological record captures variation in the *material results* of behaviour through time and space. And potential explanations using processes such as selection are evaluated by examining variation in these material results. Again, selection here is broadened from it restricted definition pertaining to organismal reproduction and refers to any differential replication of entities where replication is influenced by the relative advantage some entities may have over others in an adaptive context. For example, consider the increase of shell-tempered pottery in southeast Missouri from approximately AD 500-1400. Feathers (2006) argues that this frequency change—that is, variation in the material results of behaviour—is likely explained by selection as shell-tempered pottery performed better than sand-tempered pottery within the adaptive environment of the pottery makers. The basis for this performance claim lies in the measurable differences in strength properties, fracture toughness and work-of-fracture, across different shell-tempered and sand-tempered ceramic classes. A series of other measures (permeability, yield, deformation) also suggests that ceramic strength is the empirical property under selection. Finally, spatially and temporally variable changes in firing technology and subsistence practices likely led to different adaptive environments in which some shell-tempered potteries were advantageous relative to other pottery types.

Obviously, human behaviour is inferred throughout this possible explanation. People worked clay into vessels with variable amounts and kinds of temper. They fired pots at different temperatures and over different lengths of time. They ate different proportions and types of "wild" foods and tended crops, cooking them in various ways. But archaeologists do not observe this historically contingent pot-making, fire-stoking, and food preparing. Instead, we determine the evolutionary processes that shaped the distribution of different behaviours in a population where those different behaviours are unambiguously linked to empirical results in the archaeological record: vessel tempering behaviour that is parsed in our construction of ceramic classes, firing behaviour evidenced in ceramic cores and experimental refiring measurements, subsistence behaviour that is captured in human bone chemistry. These behavioral inferences rely on immanent (Lyman and O'Brien 1998) or universal properties and processes that link the archaeological record and human behaviour. Sometimes our assumptions about universal processes and properties will be unhelpful or unsupportable, but these may often be classification or analytical errors. We may, for example, inaccurately describe firing behaviour from sherd cores due to misclassification or unrecognised reactions between ceramic phases. Nevertheless, firing environment, and therefore this aspect of human behaviour, always influences certain sherd characteristics.

Other differences between evolutionary archaeology and dual-inheritance theory are noted in Table 2. Temporal perspective is often markedly different in the two approaches. Methods, the procedures we employ to quantify our observations in meaningful ways, may be different in each kind of study, with greater emphasis on mathematical modelling in dual-inheritance frameworks. Data are different, typically observations of behaviour for dual-inheritance theory and observations of the results of behaviour or artefacts for evolutionary archaeology. And the construction of observational units is treated differently. In the evolutionary archaeology literature, much effort has been spent on the procedures for substantiating the ability of artefact classes, either newly constructed classes (e.g., O'Brien et al. 2002) or those used by culture historians (e.g., Lipo et al. 1997), to measure evolutionary relatedness. Classes might also be evaluated on their ability to track similarity and differences due to similar natural and social environments (e.g., Hurt and Rakita 2001). In contrast, how to construct and evaluate the ability of observational units to track either homologous or analogous similarity has received little attention in the dual-inheritance literature. At least one likely reason for this is the relative ease of identifying homologous similarities, those arising from cultural transmission within related lineages, in ethnographic and experimental populations.

What are some ramifications of the theoretical differences between dual-inheritance and evolutionary archaeology approaches suggested by Table 2? Theory, laments Wilson (1998:52), is "a word hobbled by multiple meanings…[and] in everyday context shot through with corrupting ambiguity." In the natural sciences, theory is a set of propositions that order the world of investigation built by a dialectic cycle of abstract reasoning and observation. Theory provides the rules by which we try to understand the world, the pertinent observational units, and the explanatory relationships between those units (Dunnell 1982, Lewontin 1974, Willer and Willer 1974). Even with this simplified definition, some theoretical elements of dual-inheritance and evolutionary archaeology approaches should be different as the approaches were built with different kinds of observable phenomena in mind. For example, dual-inheritance theory postulates different transmission routes—vertical, horizontal, and oblique—and these different routes may partly explain the distribution of culturally transmitted variants in successive generations. There are numerous empirical studies of human behaviour that use these different routes as explanatory concepts (Boyd and Richerson 1985: Table 3.4). There are very few (e.g., Henrich 2004, MacDonald 1998) archaeological studies that use transmission route concepts in attempts to explain archaeological variation. One reason there are few uses of transmission route concepts in archaeological explanations is the difficulty of unambiguously relating archaeological observational units to transmission routes. This is not to say that transmission routes are unimportant in explanations of behavioural variation, simply that they are less easily applied in explanations of the archaeological record. Imagine a similar situation in palaeontology and evolutionary ecology. Biologists may explain increased reproductive success of particular males in a living population to be a result of rank in a dominance hierarchy (Emlen and Oring 1977). A dominance hierarchy model may not be viable for paleontologists studying the differential representation of morphological traits in extinct taxa, because mating behaviour is not observable and the timescale of interest is orders of magnitude different. This does not mean that in general dominance hierarchy models are missing some necessary component (i.e., dynamically insufficient), but are simply, like all aspects of scientific theory, built to explain a bounded portion of the empirical world.

The general applicability of transmission route concepts to the behavioural and archaeological records exemplifies one difference between dual-inheritance and evolutionary archaeology approaches. Two additional important differences include the prevalent use of decision rules in dual-inheritance studies, and the greater concern with classification issues in evolutionary archaeology.

Can decision rules be used to explain archaeological variation? Decision rules describe how different conditions influence the probability that cultural variants will be transmitted between individuals in population and include, for example, frequency-dependent transmission and guided variation (Boyd and Richerson 1985). The use of decision rules to explain the archaeological record includes a few studies that employ Neiman's (Neiman 1995) neutral model as a baseline and explain variant frequencies that depart from neutral expectations as evidence for the workings of particular decision rules (e.g., Bentley and Shennan 2003, Kohler et al. 2004, Shennan and Wilkinson 2001). Another, less used approach in archaeology, applies decision rule expectations directly to archaeological distributions without comparison to neutral null expectations. These studies seem to concentrate on what is often considered adaptive artefactual variation (e.g., Bettinger and Eerkens 1999, Henrich 2004).

Decision rules are sorting mechanisms and are conceptually similar to artificial selection in that the diversity of behaviours transmitted in a population is modified by human decisions, intentional or not. The problematic issue for archaeologists, however, is how to link decision rule expectations to distributional data generated through the creation and application of artefact classes. And when archaeological distributions match decision rule expectations, what are the explanatory alternatives and how are these assessed? Bettinger and Eerkens (1999) provide a recent example of the archaeological use of decision rules. They demonstrated that various metric attributes of Rosegate type projectile points in central Nevada are significantly correlated while attributes of the same point type in eastern California are not. Bettinger and Eerkens hypothesise that attribute correlation in central Nevada Rosegate points is a result of individuals copying all the point attributes of successful models or indirectly biased transmission. They suggest the uncorrelated attributes in eastern California Rosegate points are a result of individuals copying the points of successful model ands then modifying some point attributes in a trial-and-error fashion. This is guided variation. As Bettinger and Eerkens (1999:240) note, these hypotheses need further evaluation. One possible evaluative method involves experimental transmission studies (e.g., McElreath et al. 2005). Indeed, recent work by Mesoudi and O'Brien (2006) confirms that within an experimental population of university undergraduates variation in attribute correlation across projectile points can be a product of indirect bias and guided variation.

Even with experimental work, evaluating decision-rule hypotheses applied to archaeological data will be difficult (although difficulty is certainly not a reason to forgo this work). Experimental transmission studies might initially target particular archaeological hypotheses for evaluation (as did Mesoudi and O'Brien [2006]) and will require more complicated experiments when more complex decision-making rules are proposed such as prestige-biased transmission (Henrich and Gil-White 2001), or rules that dictate transmission with individuals sharing similar ethnic markers (Mc Elreath, Boyd, and Richerson 2003). In addition to experimental transmission analyses, research that evaluates the relative performance of artefacts in adaptive contexts may provide a methodological bridge between dual-inheritance and evolutionary archaeology.

Along with differences in the use of transmission routes and decision rules, there are also differences between dual-inheritance and evolutionary archaeology approaches in the use and construction of observational units. As mentioned at the beginning of this chapter, evolutionary archaeologists have a somewhat uncommon concern with constructing artefact classifications. The primary reason for continuous development and evaluation of artefact classifications is the requirement for any evolutionary study to describe the archaeological record in a fashion that identifies similarities resulting from transmission. Those who study and model living populations can analytically define a transmitting population as the individuals under study. Allowing for variation in human perception (Eerkens 2000), observed variation is unambiguously interpreted as a partial product of transmission between individuals. Archaeologists, however, confront an empirical record comprising the results of behaviour and often a record that preserves these results only on a corporate scale and over time spans much greater than living populations. Thus a necessary initial question to ask in evolutionary analysis of the archaeological record is how to construct observational units that track cultural transmission? Any observational unit—ethnographic or emic pottery types, chemical compositional groups, attribute-association types—may not track variation explicable via transmission. Increasingly, archaeologists and others have developed distributional and statistical expectations for artefact classes that track transmission (e.g., Lipo 2001, Neiman 1995, O'Brien et al. 2002, Pocklington 2006).

Lipo (2001), for example, used expectations for the distribution of selectively-neutral traits in a population and random walk tests to evaluate the degree to which ceramic classes applied to Mississippi river valley assemblages captured neutral culturally-transmitted variation. Lipo then used these classes to build frequency seriations of contemporaneous assemblages. Sets of successfully seriated assemblages demarcate the spatial location of a population defined by transmission and heritable continuity (see also Lipo et al. 1997).

O'Brien et al. (2002) used a form of occurrence seriation similar to a multi-state transformation series analysis in cladistics to test the ability of their projectile point classes to measure transmission. Their seriations arrange projectile point classes in a series of equally parsimonious sequences (i.e., each with the same number of character state transformations) and indicate which projectile point class is likely the most ancestral of the group. Describing occurrence seriation, O'Brien et al. (2002:141-142) argue that when the technique is properly applied and units are arranged so character presence/absence is continuous and overlapping, "the result is strong supporting evidence that we are dealing with heritable continuity" (see O'Brien and Lyman [1999] for expanded discussion of seriation).

These differences between the dual-inheritance and evolutionary archaeology programs stem in part from the different empirical records that are their major focus of explanation. However, as both programs share the goal of explaining human cultural variation as a result of transmission, selection, innovation and other evolutionary processes, some elements of each program should be compatible and beneficial to both the archaeological and behavioural records. This would also be expected if we consider that dual-inheritance theory and evolutionary archaeology can be differentiated as micro- and macroevolutionary studies, respectively (Mesoudi et al. 2006). The next section presents an example of how dual-inheritance concepts and evolutionary archaeology may be combined using the archaeology of ceramic change in the southwest Pacific.

A COMBINED EVOLUTIONARY HYPOTHESIS FOR FIJIAN CERAMIC CHANGE

Ceramic types in the archipelagos of the southwest Pacific have often been linked to culturally distinct groups. Different kinds of ceramics, often identified through various surface treatments, have suggested new populations moving into an area, or cultural change within a population over time. The Lapita ceramic series, for example, is generally interpreted as one marker of a culturally distinct population that colonised a large area of the southwest Pacific approximately 3500-3000 years ago (Kirch 1997). Unique ceramic changes in a number of archipelagos first inhabited by this population suggest later cultural differentiation (Spriggs 2004). Such explanations of ceramic variation in the Pacific are similar to the socio-cultural interpretations of phases produced by Americanist culture historians (Cochrane 2005, Hunt 1986). In contrast, pottery variation in the Pacific has rarely been explained as a result of evolutionary processes as developed within a dual-inheritance or evolutionary archaeology framework.

In the remainder of this chapter I develop an evolutionary hypothesis to account for changes in the thickness of ceramic vessels over a 2,700 year period on Waya Island in the Yasawa Islands of western Fiji. Previous research in Fiji has concentrated on chronological and spatial variation in ceramic surface treatment and vessel forms, often interpreted in terms of intra- and inter-archipelagic interaction in the region. The goal of the analysis here is to exemplify ways in which the strengths of evolutionary archaeology and dual-inheritance approaches can be combined in a framework for archaeological explanation.

The Yasawa Islands of western Fiji (Figure 1) comprise six main islands and several islets stretching some 80 km in a straight line 40 km west of the main Fijian island of Viti

Levu. The Yasawas were initially inhabited approximately 2700 years ago, two hundred years later than the first occupied areas of Fiji (Anderson and Clark 1999, Cochrane 2004). Yasawas Islands archaeological deposits contain abundant low-fired earthenwares with a range of decorative and formal variation used to divide Fijian prehistory into periods (Table 3). Pottery in the Yasawas and Fiji appears to have been produced at a household level as there is currently no evidence for large-scale manufacturing or functional integration of different production units.

Archaeological research in the Yasawa Islands has consistently been concerned with generating descriptions of the archaeological record with classification systems that track heritable continuity (Cochrane 2002b, Cochrane 2004, Cochrane in press), a methodological focus of evolutionary archaeology as described above. Similarities in Yasawa Islands ceramics, when described using classes built from particular observations or modes, describe transmission patterns spanning the human occupation of the islands. The spatial and temporal characteristics of these transmission patterns have been generated through both cladistic and seriation analyses (Cochrane 2004).

Seriation analysis of the Yasawa Islands ceramic assemblages, described by various surface treatment classes, indicates the distribution of surface treatment classes over time and across the Yasawa Islands is likely a product of cultural transmission. Figure 2 depicts a seriation where surface modification class frequencies are monotonically distributed over assemblages from across the Yasawa Islands and from deposits dating to colonisation up to the recent past. This seriation, however, does not conform perfectly to the model as the distribution of two classes, Rectangular Paddle Impressing and Rectilinear Incision, are not monotonic and continuous. The other class distributions follow the seriation model within the 95% confidence intervals for estimating the frequency of classes. Finally, the assemblage from Y2-39 (8-1), is not described by multiple classes that *overlap* with other assemblages in the order.

Even though these Yasawa Islands assemblages do not conform in all respect s to the frequency seriation model it seems likely that with larger assemblages more conditions of the model will be met (Lipo 2001). If future research on assemblages representing the entire prehistory of the islands bears this out then we can suggest that the Yasawas islands were inhabited by a single population sharing traits through cultural transmission from colonisation up to the recent past.

Phylogenetic transmission patterns were also explored in the Yasawa Islands assemblages with trees generated using maximum-parsimony methods in PAUP* 4.0 (Swofford 2001). The phylogenetic analyses were conducted on some of the same archaeological assemblages used in the seriation analysis, but for the phylogenetic analysis only sherds described by a rim classification were used. This classification was evaluated in the same manner presented in O'Brien et al. (2002). Several phylogenetic trees and their clades, or groups of related transmission lineages at several hierarchical levels, were generated and two are arrayed against a time-line in Figure 3. These phylogenetic trees of ceramic classes are constructed with different, but equally applicable outgroups, and share similar topologies each depicting a clade of recent ceramic classes evolved from a common pool of ancestral variation approximately 500 years ago (see Cochrane [2004] for full analysis]).

With methods such as seriation and cladistics, along with evolutionary archaeology's typical concern with artefact classification, we can define both Darwinian populations and transmission lineages within these populations. A logical next step is to develop hypotheses to account for spatial and temporal variation among populations (e.g., Lipo et al. 2005) or among transmission lineages within populations, such as the origins of the recent clade of ceramic rim classes (e.g., Cochrane and Neff 2006). In accounting for variation within and between populations, evolutionary archaeology and dual-inheritance theory find close common interest.

A transmission lineage is an empirical distribution of an artefact class or classes where the distribution conforms to the expectations of heritable continuity (O'Brien and Lyman 2000). How might we explain the spatial, temporal, and class characteristics of a lineage relative to other lineages or clades? Consider for example a lineage defined by steatite vessel classes relative to other container technologies, say pottery, sandstone and basket classes all joined in a clade of related transmission lineages. The temporal and spatial distribution of the steatite class lineage might be explained by a relative advantage these vessels exhibit compared to other container technologies (Truncer 2004). First we should demonstrate that all of these container classes were present within a population of cultural transmitters. Second, both steatite vessel class frequencies and independent measures of relative advantage, such as offered through material science experiments, would have to conform to a model of traits under selection—differential persistence related to relative advantage in a particular environment. This logic has been adopted by evolutionary archaeologists and others (e.g., Braun 1987, Feathers 1989, Hoard et al. 1995, O'Brien et al. 1994, Schiffer and Skibo 1987, 1997). In a similar sense, dual-inheritance theory suggests that variation in the expression of a cultural trait in a lineage may be explained by cultural transmission or decision rules consciously or unconsciously adopted by individuals in a population. Different decision rules produce different expected distributions of cultural trait variants and most decision rules are based on the assumption that variants differ in potential adaptiveness.

However, selection in dual-inheritance theory refers to the differential persistence of genes, natural selection *sensu stricto*, not the generalized meaning favoured by evolutionary archaeology as the differential persistence of inherited variants in either the separate genetic or cultural transmission systems (Leonard and Jones 1987, Neff 2000, O'Brien and Lyman

2002). Thus natural selection in dual-inheritance theory shapes cultural trait distributions through the removal of models (people) from which naïve individuals might have learned cultural traits (Boyd and Richerson 1985:174-175), although many dual-inheritance models suggest natural selection plays little part as its effects are overwhelmed by the effects of learning.

How might decision rules as developed within dual-inheritance theory and the generalized model of selection in evolutionary archaeology be used to explain variation within a lineage? To address this, I examined change in sherd thickness over time at the Qaranicagi cave site on Waya Island in the Yasawa Islands of western Fiji. Deposits at Qaranicagi cover the 2,700 years of human occupation in the Yasawas and pottery deposition at this site was fairly continuous (Cochrane 2002b). The site was used for a range of activities including food processing and consumption, evidenced by midden deposits of fish, shellfish, mammal, and bird remains, and multiple hearth features. Ceremonial burial activities also took place within the confines of the cave and lithic tools and debitage indicate tool use and manufacture or retouch within the site (Cochrane 2004, Cochrane et al. 2004). Assessment of the heritability of vessel thickness at Qaranicagi has not been completed. For the moment, we must rely on the analyses of ceramic rim form and decoration that indicate variation in these cultural traits is a product of transmission within one or more lineages in a population and assume that the thickness of these vessels was also a learned trait passed between individuals over the time span of the Qaranicagi ceramic sequence.

A first step in analysing thickness variation here is to compare sherd thickness with expectations based on a null model. A stochastic null model has been developed in both the dual-inheritance theory and evolutionary archaeology frameworks: unbiased transmission (Boyd and Richerson 1985) and the neutral model (Lipo 2001, Neiman 1995), respectively. These models propose that trait frequencies in a cultural generation are a product of prior frequencies, the rate of innovation and effective population size, and trait frequencies are not affected by differential persistence due to relative advantage. Neutral model evaluations have previously been made using estimates of class diversity following Neiman (1995) and comparing variant frequencies to power law distributions (e.g., Bentley et al. 2004, Bentley and Shennan 2003). Recently Eerkens and Lipo (2005) formulated an unbiased transmission model where transmission of a continuous trait was simulated for ten related lineages. They noted that if the only process influencing trait expression is copying error then the value of the trait in each related lineage will diverge, the mean value across all lineages will stay roughly constant and the coefficient of variation will increase over successive transmission generations (Figure 4).

The Eerkens and Lipo model may explain sherd thickness data generated from the superposed pottery deposits at Qaranicagi. In comparison with their simulation, if vessel thickness is a cultural trait transmitted within a group of related lineages, and if variation in vessel thickness is explained solely by copying error, and not for example by a relative advantage conferred to vessels of different thickness, the mean of thickness should remain the same within set confidence intervals over transmission generations. A plot of sherd thickness means across excavation levels, combined to reduce effects of sample size, indicates that mean sherd thickness does not remain the same (Figure 5). Moreover mean sherd thicknesses are significantly different ($F = 43.18$, $p < 0.0005$), although the outlier and extreme values may affect this ANOVA. These results suggest that variation in sherd thickness is not explained by a null model of copying error. Analysis of the coefficient of variation of the sherd data supports this conclusion as well.

The coefficient of variation (CV) is one of several ways to characterise the amount of variation in a population measured by a variable. It is calculated by dividing the standard deviation of a set of measurements by the mean of the measurements and multiplying the quotient by 100. Like the mean, the CV of sherd thickness changes over time (Figure 6). It decreases steadily from the earliest excavation levels at Qaranicagi until approximately level 6 (circa 550 years ago), then the CV increases for the remainder of the sequence.

How might we apply the expectations of other decision rules to variation in the CV of body sherd thickness at Qaranicagi? Again, Eerkens and Lipo (2005) provide some null-model expectations as they simulated the effect of various forms of biased transmission on variance. They simulated conformist transmission where individuals acquiring traits may conform to an average value from the previous transmission generation, and prestige-biased transmission, where individuals may preferentially copy models from the previous generation based on the model's prestige. The strength of either conformity or prestige-bias was altered for different simulation runs by changing the probability that individuals conform or choose a prestigious model. Eerkens and Lipo (2005) demonstrate that as the probability of either conformist or prestige-biased transmission increases, variance in the transmitted trait decreases.

Comparing the Eerkens and Lipo simulation results with the Fijian data suggest that the decrease in the CV of sherd thickness over the first 2,200 years of the Qaranicagi sequence might be explained by biased transmission, of either a conformist or prestige-based sort. To further investigate this we can examine the coordination of trends in the CV of sherd thickness and thickness values themselves. Comparison of Figures 6 and 7 shows that while CV was decreasing from initial occupation of Qaranicagi 2,700 years ago up to approximately 550 years ago, the trend in sherd thickness was to first increase and then continually decrease until about 550 years ago (although the regression in Fig. 7 explains very little of the variation). For the last 550 years both the CV of sherd thickness and sherd thickness values increase.

Conformist transmission increases the frequency of adaptive cultural variants in a population (Boyd and Richerson 1985, Henrich and Boyd 1998). Therefore at Qaranicagi if vessel thickness variants are sorted by conformist transmission they should exhibit adaptive differences relative to a selective environment. Such adaptive differences have been evaluated by evolutionary archaeologists and others through material science analyses that attempt to quantify the differing performance of variants in particular contexts (e.g., Feathers 2006, Lyman et al. 1998, O'Brien et al. 1994, Schiffer and Skibo 1987, 1997). Vessel thickness is one characteristic that influences the ability of pots to withstand the compressive and tensile forces on their exterior and interior surfaces when placed over a fire (other inter-related characteristics include porosity, paste-grain and temper-grain size). Thin vessels, with higher thermal conductivity than thick vessels, are better able to resist the damaging effects of thermal stress because they have a smaller thermal gradient from exterior to interior. Thus we might expect to find thinner vessels when and where prolonged and/or repeated cooking in pots is advantageous compared to other food preparation technologies. For the Qaranicagi ceramics the possible performance differences related to thermal stress between vessels of varying thickness could be assessed through thermal gradient analysis (see Lawrence and West 1982) of test specimens constructed to represent the range of thickness variants with their other ceramic characteristics (porosity, grain sizes).

Combining the adaptive logic of performance analyses and the conformist transmission hypothesis, we would expect a change in the selective environment that sorts variation in cooking technologies and vessel thickness at approximately 2300 years ago when the trend changes from increasingly thick vessels to increasingly thin vessels occurs. Additionally, as the CV of sherd thickness is continually decreasing before and after the thickness trend change, it seems that the strength of selection potentially shaping sherd thickness is continually increasing during the first 2200 years of occupation. Testing this expectation of the conformist transmission hypotheses might involve investigating dietary changes that require changes in cooking technology related to prolonged or repeated cooking over heat. Such dietary changes could be described through, for example, archaeofaunal, phytolith and human bone isotope analyse. Protein and residue analyses of potsherds can provide direct evidence of changes in the kinds of foods consumed. Although some isotopic (Cochrane et al. 2005) and faunal analyses (Hunt et al. 1999) have begun, additional work is necessary to evaluate the conformist transmission hypothesis in this manner.

Alternatively, if prestige-based transmission explains the decrease in the CV of sherd thickness for the first 2,200 years at Qaranicagi what corollary empirical expectations related to sherd thickness trends can we derive? Here, it seems most expectations would be plagued by causal equifinality given our empirical record of artefacts along with their temporal and spatial variation, and the behavioural record often used to generate empirical expectations for prestige-biased transmission (Henrich and Gil-White 2001). While some may argue that the corollary expectations of dietary change in the conformist transmission hypothesis are also troubled by equifinality, it is material science analysis of performance differences that will provide an empirical link between ceramic thickness variation and the selective environment that sorts cooking technologies and subsistence variation. This is not to say that pot makers never engaged in preferential copying of cliques or particular models. Like the example in the previous section of paleontologists struggling to use dominance hierarchy models to explain reproductive success, we can expect that some aspects of dual-inheritance theory will not be applicable to the archaeological record.

Trends in sherd thickness might also be explained through hierarchical sorting, or hitch-hiking (Hurt et al. 2001, Vrba and Gould 1986). Hierarchical sorting occurs when an evolutionary process such as selection has shaped the differential representation of entities at a particular level in a hierarchy such that lower-level entities are also differentially represented. This process may explain the differential persistence of thickness variants at

Qaranicagi as summarised by the trend in the CV of sherd thickness. For example, different vessel types (e.g., water storage, food storage, cooking, ceremony, and transportation vessels) may have different functional thickness parameters. If there is a reduction in the diversity of vessel types, perhaps as a result of selection removing vessel repertoires that are more costly in terms of time, knowledge and materials to produce (Cochrane 2002b), then different sets of thickness parameters associated with vessel types may also be removed—this is hierarchical sorting. The trend toward lower CV of sherd thickness values during the first 2,200 years at Qaranicagi may be tracking the changing diversity of vessel types over time and the removal of vessel types with widely varying thickness parameters. Indeed archaeologists have for some time noted a decrease in vessel type diversity beginning shortly after colonisation of Fiji and the nearby archipelagos of Tonga and Samoa (analyses summarised by Burley and Clark [2003]). Additionally, unlike other areas of Fiji-West Polynesia where vessel type diversity decreases throughout prehistory, Burley (2005) has recently argued that at the Sigatoka Dunes site in western Fiji (the same general area as Qaranicagi), this trend of declining vessel type diversity stops approximately 1,600 years ago and diversity increases as new vessel types begin to appear in the Sigatoka ceramic assemblages. Although vessel type diversity data for Qaranicagi are inconclusive on this point (Cochrane 2002b, 2004), the late increase in the CV of sherd thickness at Qaranicagi may also reflect the addition of vessel types that expand the thickness parameters employed by potters.

CONCLUSION

Explanation of the archaeological record can apply insights and models from dual-inheritance theory constructed largely to explain observable behaviour, but we are limited in our use of dual-inheritance transmission models when the archaeological record is the focus of explanation. In the Qaranicagi ceramics example, a conformist transmission explanation can be evaluated by investigating the ceramic performance expectations of potentially adaptive traits and corollary expectations of archaeological patterning. A prestige-based transmission model, however, seems to have no unambiguous additional empirical expectations even though both models would produce similar patterns in the coefficient of variation (CV) of ceramic traits.

The differences between the explanatory frameworks of paleontology and evolutionary biology are closely paralleled in evolutionary archaeology and dual-inheritance frameworks. Evolutionary archaeology and dual-inheritance theory are built primarily to explain different empirical records—the record of artefacts and the living record of behaviour. An archaeological explanatory system cannot necessarily be built from only those processes that explain living systems, but instead needs to be built in dynamically and empirically sufficient terms using insights from both dual-inheritance and evolutionary archaeology theory. Gould (1980) recognised a similar problem when paleontologists continued to apply microevolutionary processes to the fossil record.

Several years ago Bettinger and Eerkens (1999:239) suggested that "there is a general tendency for archaeologists to assume that differences in cultural transmission are unimportant. We suppose that reflects a common misconception that Darwinian forces are all obvious, strong, and life threatening." Now an apt statement might read: while archaeologists increasingly recognise the importance of cultural transmission, some concepts from dual-inheritance theory built to explain a behavioural record may lack empirical sufficiency when dealing with the archaeological record.

ACKNOWLEDGEMENTS

This chapter has benefited from the suggestions of Stephen Shennan and two anonymous reviewers to whom I owe my thanks.

REFERENCES

Allen, M., S. 1996. Style and function in East-Polynesian fishhooks. *Antiquity* 70:97-116.

Anderson, A., and G. Clark. 1999. The age of Lapita settlement in Fiji. *Archaeology in Oceania* 34:31-39.

Bentley, R. A., M. W. Hahn, and S. Shennan. 2004. Random drift and cultural change. *Proceedings of the Royal Society of London* 271:1143-1450.

Bentley, R. A., and S. J. Shennan. 2003. Cultural Transmission and Stochastic Network Growth. *American Antiquity* 68:459-485.

Best, S. 2002. *Lapita: a View from the East*. Vol. 24. *New Zealand Archaeological Association Monograph*. Auckland: New Zealand Archaeological Association.

Bettinger, R. L., and J. W. Eerkens. 1999. Point Typologies, Cultural Transmission, and the Spread of Bow-and-Arrow Technology in the Prehistoric Great Basin. *American Antiquity* 64:231-242.

Birks, L. 1973. *Archaeological Excavations at Sigatoka Dune Site, Fiji*. Vol. 1. *Bulletin of the Fiji Museum*. Suva, Fiji: Fiji Museum.

Boyd, R., and P. J. Richerson. 1985. *Culture and the Evolutionary Process*. Chicago: University of Chicago Press.

Braun, D. P. 1987. "Coevolution of Sedentism, Pottery Technology, and Horticulture in the Central Midwest, 200 B.C. - A.D. 600," in *Emergent Horticultural Economies of the Eastern Woodlands*, vol. 7, *Occasional Paper*. Edited by W. F. Keegan, pp. 153-181. Carbondale: Southern Illinois University.

Bronitsky, G. 1986. "The Use of Materials Science Techniques in the Study of Pottery Construction and Use," in *Advances in Archaeological Method and Theory*, vol. 9. Edited by M. B. Schiffer, pp. 206-276. Orlando: Academic Press.

Burley, D. V. 2003a. "Dynamic Landscapes and Episodic Occupations: Archaeological Interpretation and Implications in the Prehistory of the Sigatoka Sand Dunes," in *Pacific Archaeology: assessments and prospects*, vol. 15, *Les Cahiers de l'Archaéologie en Nouvelle Calédonie*. Edited by C. Sand, pp. 307-315. Nouméa: Service des Musées et du Patrimonie de Nouvelle-Calédonie.

—. 2005. Mid-Sequence Archaeology at the Sigatoka Sand Dunes with Interpretive Implications for Fijian and Oceanic Culture History. *Asian Perspectives* 44:320-348.

Burley, D. V., and W. R. Dickinson. 2004. Late Laptia occupation and its ceramic assemblage at the Sigatoka Sand Dune site, Fiji, and their place in Oceanic prehistory. *Archaeology in Oceania* 39:12-25.

Burley, D. V. and J. T. Clark 2003. The Archaeology of Fiji/West Polynesia in the post-Lapita Era. In *Pacific Archaeology: assessments and prospects*, edited by C. Sand, pp. 235-254. Les Cahiers de l'Archaéologie en Nouvelle Calédonie. vol. 15. Service des Musées et du Patrimonie de Nouvelle-Calédonie, Nouméa.

Cavalli-Sforza, L. L., and M. W. Feldman. 1981. *Cultural Transmission and Evolution: A Quantitative Approach*. Vol. 16. *Monographs in Population Biology*. Princeton: Princeton University Press.

Clark, G. 2000. "Mid-Sequence Isolation in Fiji 2500-1000 BP," in *Indo-Pacific Prehistory: The Melaka Papers*, vol. 19, *Bulletin of the Indo-Pacific Prehistory Association*. Edited by P. Bellwood, D. Bowdery, D. Bulbeck, D. Baer, V. Shinde, R. Shutler, and G. Summerhayes, pp. 152-158. Canberra: Australian National University.

Clark, G. R. 1999. Post-Lapita Fiji: cultural transformation in the mid-sequence. Ph D Dissertation, Australian National University.

Cochrane, E. E. 2001. "Style, Function, and Systematic Empiricism: The Conflation of Process and Pattern," in *Style and Function: Conceptual Issues in Evolutionary Archaeology*. Edited by T. D. Hurt and G. F. M. Rakita, pp. 183-202. Westport, Conn.: Bergin and Garvey.

—. 2002a. "Separating Time and Space in Archaeological Landscapes: An Example from Windward Society Islands Ceremonial Architecture," in *Pacific Landscapes: Archaeological Approaches*. Edited by T. N. Ladefoged and M. W. Graves, pp. 189-209. Los Osos, CA: Easter Island Foundation Press.

—. 2002b. Explaining the Prehistory of Ceramic Technology on Waya Island, Fiji. *Archaeology in Oceania* 37:37-50.

—. 2004. Explaining Cultural Diversity in Ancient Fiji: the Transmission of Ceramic Variability. Unpublished Ph. D. dissertation, University of Hawaii.

—. 2005. Review of "Pacific Archaeology: Assessments and Prospects," C. Sand (ed.). *Asian Perspectives* 44:407-410.

—. in press. "Migration and Cultural Transmission: investigating human movement as an explanation for Fijian ceramic change," in *Cultural Transmission in Archaeology: Issues and Case Studies*. Edited by M. J. O'Brien. Washington, D.C.: Society for American Archaeology.

Cochrane, E. E., and H. Neff. 2006. Investigating Compositional Diversity among Fijian Ceramics with Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS): Implications for Interaction Studies on Geologically Similar Islands. *Journal of Archaeological Science* 33:378-390.

Cochrane, E. E., M. Pietrusewsky, and M. T. Douglas. 2004. Culturally Modified Human Remains Recovered from an Earth-oven Interment on Waya Island, Fiji. *Archaeology in Oceania* 39:54-59.

Cochrane, E. E., J. Field and D. M. Greenlee
2005 Variation in Isotopic Diet Among Prehistoric Fijians, Poster presented at the 70th annual meeting of the Society for American Archaeology, Salt Lake City, Utah.

Collard, M., S. J. Shennan, B. Buchanan and R. A. Bentley 2007. Evolutionary Biological Methods and Cultural Data. In *Handbook of Archaeological Theories*, edited by R. A. Bentley, H. D. G. Maschner and C. Chippendale. AltaMira Press, Lanham, Maryland, in press.

Dunnell, R. C. 1982. Science, Social Science and Common Sense: The Agonizing Dilemna of Modern Archaeology. 38:1-25.

—. 1995. "What Is It That Actually Evolves?" in *Evolutionary Archaeology: Methodological Issues*. Edited by P. A. Teltser, pp. 33-50. Tucson: University of Arizona Press.

Eerkens, J. W. 2000. Practice Makes Within 5% of Perfect: Visual Perception, Motor Skills, and Memory in Artifact Variation. *Current Anthropology* 41:663-668.

Eerkens, J. W., and C. P. Lipo. 2005. Cultural transmission, copying errors, and the generation of variation in material culture and the archaeological record. *Journal of Anthropological Archaeology* 24:316.

Eldredge, N., and S. J. Gould. 1972. "Punctuated equilibria: An alternative to phyletic gradualism," in *Models in Paleobiology*. Edited by T. J. M. Schopf. San Francisco: Freeman, Cooper.

Emlen, S. T., and L. W. Oring. 1977. Ecology, Sexual Selection, and the Evolution of Mating Systems. *Science* 197:215-223.

Feathers, J. K. 1989. Effects of Temper on Strength of Ceramics: Response to Bronitsky and Hamer. *American Antiquity* 54:579-588.

—. 2006. Explaining Shell-Tempered Pottery in Prehistoric Eastern North America. *Journal of Archaeological Method and Theory* 13(2):89-133.
Field, J. 2004. Environmental and climatic considerations: a hypothesis for conflict and the emergence of social complexity in Fijian prehistory. *Journal of Anthropological Archaeology* 23:79-99.
Ford, J. A. 1952. Measurements of Some Prehistoric Design Developments in the Southeastern States. *American Museum of Natural History Anthropological Papers* 43:313-384.
Frost, E. L. 1979. "Fiji," in *The Prehistory of Polynesia*. Edited by J. D. Jennings, pp. 61-81. Cambridge: Harvard University Press.
Futuyma, D. J. 1998. *Evolutionary Biology*. 3rd ed. Sinauer, Sunderland, Massachusetts.
Gould, S. J. 1980. The Promise of Paleontology as a Nomothetic Discipline. *Paleobiology* 6:96-118.
Gould, S. J., and N. Eldredge. 1977. Punctuated equilibria: The tempo and mode of evolution reconsidered. *Paleobiology* 3:115-151.
Grantham, T. 2004. The role of fossils in phylogeny reconstruction: Why is it so difficult to integrate paleobiological and neontological evolutionary biology. *Biology and Philosophy* 19:687-720.
Green, R. C. 1963. A Suggested Revision of the Fijian Sequence. *Journal of the Polynesian Society* 72:235-253.
Henrich, J. 2004. Demography and Cultural Evolution: How Adaptive Cultural Processes Can Produce Maladaptive Losses--the Tasmanian Case. *American Antiquity* 69:197-214.
Henrich, J. and R. Boyd 1998. The Evolution of Conformist Transmission and the Emergence of Between-Group Differences. Evolution and Human Behavior 19(4):215.
Henrich, J., and F. J. Gil-White. 2001. The evolution of prestige - Freely conferred deference as a mechanism for enhancing the benefits of cultural transmission. *Evolution And Human Behavior* 22:165-196.
Hoard, R. J., M. J. O'Brien, M. G. Khorasgany, and V. S. Gopalaratnam. 1995. A Materials-Science Approach to Understanding Limestone-Tempered Pottery from the Midwest. *Journal of Archaeological Science* 22:823-832.
Hunt, T. L. 1986. "Conceptual and Substantive Issues in Fijian Prehistory," in *Island Societies: Archaeological Approaches to Evolution and Transformation*. Edited by P. V. Kirch, pp. 20-32. Cambridge: Cambridge University Press.
—. 1987. Patterns of Human Interaction and Evolutionary Divergence in the Fiji Islands. *Journal of the Polynesian Society* 96:299-334.
Hurt, T. D., and G. F. M. Rakita. Editors. 2001. *Style and Function: Conceptual Issues in Evolutionary Archaeology*. Westport, Conn.: Bergin and Garvey.
Hurt, T. D., T. L. VanPool, G. F. M. Rakita and R. D. Leonard 2001. Explaining the Co-occurence of Traits in the Archaeological Record: A Further Consideration of Replicative Success. In *Style and Function: Conceptual Issues in Evolutionary Archaeology*, edited by T. D. Hurt and G. F. M. Rakita, pp. 51-68. Bergin and Garvey, Westport, Connecticut.
Kirch, P. 1997. *The Lapita peoples*. *The Peoples of South-East Asia and The Pacific*. Cambridge: Blackwell.
Kohler, T. A., S. VanBuskirk, and S. Ruscavage-Barz. 2004. Vessels and Villages: evidence for conformist transmission in early village aggregations on the Pajarito Plateau, New Mexico. *Journal of Anthropological Archaeology* 23:100-118.
Krebs, J. R. and N. B. Davies. 1993. An Introduction to Behavioral Ecology. 3rd ed. The Alden Press, Oxford.

Kroeber, A., L. 1919. On the Principle of Order in Civilization as Exemplified by Changes of Fashion. *American Anthropologist* 21:253-263.
Lawrence, W. G. and R. R. West 1982. *Ceramic Science for the Potter*. Chilton, Radnor, Pennsylvania.
Leonard, R. D., and G. T. Jones. 1987. Elements of an Inclusive Evolutionary Model for Archaeology. *Journal of Anthropological Archaeology* 6:199-219.
Lewontin, R. C. 1974. *The Genetic Basis of Evolutionary Change*. New York: Columbia University Press.
Lipo, C. P. 2001. *Science, Style, and the Study of Community Structure: An Example from the Central Mississippi River Valley*. Vol. 918. *British Archaeological Reports, International Series*. Oxford: Hadrian Books Ltd.
Lipo, C. P., M. Madsen, R. C. Dunnell, and T. Hunt. 1997. Population Structure, Cultural Transmission, and Frequency Seriation. *Journal of Anthropological Archaeology* 16:301-333.
Lipo, C. P., J. K. Feathers and R. C. Dunnell. 2005. Temporal Data Requirements, Luminescence Dates, and the Resolution of Chronological Structure of Late Prehistoric Deposits in the Central Mississippi River Valley. *American Antiquity* 70:527-544.
Lyman, R. L., and M. J. O'Brien. 1998. The Goals of Evolutionary Archaeology: History and Explanation. *Current Anthropology* 39:615-652.
—. 2003. Cultural Traits: Units of Analysis in Early Twentieth-Century Anthropology. *Journal of Anthropological Research* 59:225-250.
—. 2006. "Seriation and Cladistics: The Difference Between Anagenic and Cladogenic Evolution," in *Mapping Our Ancestors: Phylogenetic Methods in Anthropology and Prehistory*. Edited by C. P. Lipo, M. J. O'Brien, S. Shennan, and M. Collard. New York (in press): Aldine de Gruyter.
Lyman, R. L., M. J. O'Brien and V. Hayes 1998. A Mechanical and Functional Study of Bone Rods from the Richey-Roberts Clovis Cache, Washington, U.S.A. Journal of Archaeological Science 25:887-906.
MacDonald, D. H. 1998. Subsistence, Sex, and Cultural Transmission in Folsom Culture. *Journal of Anthropological Archaeology* 17:217-239.
McElreath, R., R. Boyd, and P. J. Richerson. 2003. Shared Norms and the Evolution of Ethnic Markers. *Current Anthropology* 44:122-129.
McElreath, R., M. Lubell, P. J. Richerson, T. M. Waring, W. Baum, E. Edsten, C. Efferson and B. Paciotti .2005. Applying evolutionary models to the laboratory study of social learning. *Evolution and Human Behavior* 26(6):483.
Meltzer, D., J. 1981. A Study of Style and Function in a Class of Tools. *Journal of Field Archaeology* 8:313-326.
Mesoudi, A., A. Whiten and K. N. Laland. 2006. Towards a unified science of cultural evolution. *Behavioral and Brain Sciences* 29:329-383.
Mesoudi, A. and M. J. O'Brien .2006. The Cultural Transmission of Great Basin Projectile-Point Technology: Experimental and Computer Simulations. Submitted to *American Antiquity*, in review.
Neff, H. 2000. On Evolutionary Ecology and Evolutionary Archaeology: Some Common Ground? *Current Anthropology* 41:427-429.
Neiman, F. 1995. Stylistic Variation in Evolutionary Perspective: Inferences from Decorative Diversity and Interassemblage Distance in Illinois Woodland Ceramic Assemblages. *American Antiquity* 60:7-36.
Nelson, N. C. 1916. Chronology of the Tanos Ruins, New Mexico. *American Anthropologist* 18:159-180.

O'Brien, M. J., T. D. Holland, R. J. Hoard, and G. L. Fox. 1994. Evolutionary Implications of Design and Performance Characteristics of Prehistoric Pottery. *Journal of Archaeological Method and Theory* 1:259-304.

O'Brien, M. J., and R. L. Lyman. 1999. *Seriation, Stratigraphy, and Index Fossils: the Backbone of Archaeological Dating*. Kluwer Academic/Plenum Publishers, New York.

—. 2000. *Applying Evolutionary Archaeology: A Systematic Approach*. New York: Kluwer Academic/Plenum Publishers.

—. 2002. Evolutionary Archaeology: Current Status and Future Prospects. *Evolutionary Anthropology* 11.

O'Brien, M. J., R. L. Lyman, Y. Saab, E. Saab, J. Darwent, and D. S. Glover. 2002. Two Issues in Archaeological Phylogenetics: Taxon Construction and Outgroup Selection. *Journal of Theoretical Biology* 215:133-150.

Pocklington, R. 2006. What is a Culturally Transmitted Unit, and How We Find One? In Mapping Our Ancestors: Phylogenetic Methods in Anthropology and Prehistory, edited by C. P. Lipo, M. J. O'Brien, M. Collard and S. Shennan, pp. 19-31. Aldine de Gruyter, New York.

Read, D. 2006. Tasmanian Knowledge and Skill: Maladaptive Imitation or Adequate Technology? *American Antiquity* 71:164-184.

Schiffer, M. B., and J. M. Skibo. 1987. Theory and Experiment in the Study of Technological Change. *Current Anthropology* 28:595-622.

Schiffer, M. B. and J. Skibo 1997. The explanation of artifact variability. *American Antiquity* 62:27-50.

Schiffer, M. B., J. M. Skibo, T. C. Boelke, M. A. Neupert, and M. Aronson. 1994. New Perspectives on Experimental Archaeology: Surface Treatments and Thermal Response of the Clay Cooking Pot. *American Antiquity* 59:197-218.

Shennan, S. 2000. Population, Culture History, and the Dynamics of Culture Change. *Current Anthropology* 41:811-835.

—. 2003. *Genes, Memes, and Human History: Darwinian Archaeology and Cultural Evolution*. London: Thames and Hudson.

Shennan, S. J., and J. R. Wilkinson. 2001. Ceramic Style Change and Neutral Evolution: A Case Study from Neolithic Europe. *American Antiquity* 66:577-593.

Simpson, G. G. 1943. Criteria for Genera, Species, and Subspecies in Zoology and Paleozoology. *New York Academy of Sciences, Annals* 44:145-178.

Smith, E. A. and B. Winterhalder (editors). 1992. Evolutionary Ecology and Human Behavior. Aldine de Gruyter, New York.

Soltis, J., R. Boyd, and P. J. Richerson. 1995. Can group-functional behaviors evolve by cultural group selection? *Current Anthropology* 36:473-494.

Spriggs, M. 2004. Is There Life After Lapita, and Do You Remember the 60s? The Post-Lapita Sequences of the Western Pacific. *Records of the Australian Museum* Supplement 29:139-144.

Swofford, D. L. 2001. "PAUP*: Phylogenetic Analysis Using Parsimony And Other Methods," 4.0 edition. Sunderland, MA: Computer program distributed by Sinaur Associates.

Teltser, P., A. 1995. "Culture History, Evolutionary Theory, and Frequency Seriation," in *Evolutionary Archaeology: Methodological Issues*. Edited by P. A. Teltser, pp. 51-68. Tucson: University of Arizona Press.

Truncer, J. 2004. Steatite Vessel Age and Occurrence in Eastern North America. *American Antiquity* 69:487-513.

Tschauner, H. 1994. Archaeological Systematics and Cultural Evolution: Retrieving the

Honour of Culture History. *Man*:77-93.
Vrba, E. S. and S. J. Gould 1986. The hierarchical expansion of sorting and selection: Sorting and selection cannot be equated. *Paleobiology* 12:217-228.
Willer, D., and J. Willer. 1973. *Systematic Empiricism: Critique of a Pseudoscience*. Englewood Cliffs, N.J.: Prentice-Hall.
Wilson, E. O. 1998. *Consilience: The Unity of Knowledge*. New York: Alfred A. Knoph.

Table 1. Grantham's (2004:690) table comparing the fields of neontological evolutionary biology and evolutionary paleobiology.

	Neontological evolutionary biology	Evolutionary paleobiology
Focus of study	Living organisms	Fossil remains of organisms
Temporal perspective	Shorter term: 10^{-2}–10^{3} years	Typically longer term: 10^{3}–10^{7} years
Theory	Models of natural selection and speciation, generally articulated in terms of population or quantitative genetics	Relies on broader neo-darwinian theory; rarely uses population genetic theory. Some distinctively paleobiological theory (e.g., taphonomy)
Methods	Greater emphasis on experiments	Less emphasis on experiments
Data	Emphasizes genetic data and population structure	Extremely limited access to genetic data and population structure

Table 2. Comparison of dual-inheritance theory and evolutionary archaeology using Grantham's (2004:690) categories.

	Dual-inheritance theory	**Evolutionary archaeology**
Focus of study	Extant and modelled populations	Archaeological record
Temporal Perspective	Less than one day to tens of years	Hundreds to millions of years
Theory	Transmission & decision rules, population genetic theory	Transmission & selection models, neutral trait models
Methods	Ethnographic field work, mathematical modelling	Seriation, cladistics, materials science/ performance analyses, less emphasis on mathematical modelling
Data	Observations of behaviour	Artefacts and the results of behaviour
Observational units	Little emphasis on how to construct observational units	Large emphasis on how to construct observational units

Table 3. Overview of Fijian prehistory. Minor variation in timing of periods not shown for simplicity, see (Best 2002, Burley 2003, Clark 1999, Green 1963).

Time Period	Period Name	Ceramics	Subsistence	Social Organization	References
2900 – 2500 BP	Sigatoka	Lapita and plainwares	generalized horticulture, marine resources	colonizing populations	(Anderson and Clark 1999, Birks 1973, Burley and Dickinson 2004, Kirch 1997)
2500 – 1000 BP	Navatu	paddle-impressed wares, plainwares	increasing horticultural variation, marine resources	population expansion, settlement shifts	(Burley 2005, Clark 2000, Cochrane and Neff 2006)
1000 – 200 BP	Vuda	plainwares, incised and appliqué wares	agriculture, horticulture, marine resources	aggregated settlements, defended habitations	(Field 2004, Hunt 1987)
200 BP - present	Rā	historic wares, appliqué wares	agriculture, horticulture, marine resources	European contact, population collapse	(Frost 1979)

Figure 1. Map of the Pacific showing Fiji and the Yasawa Islands

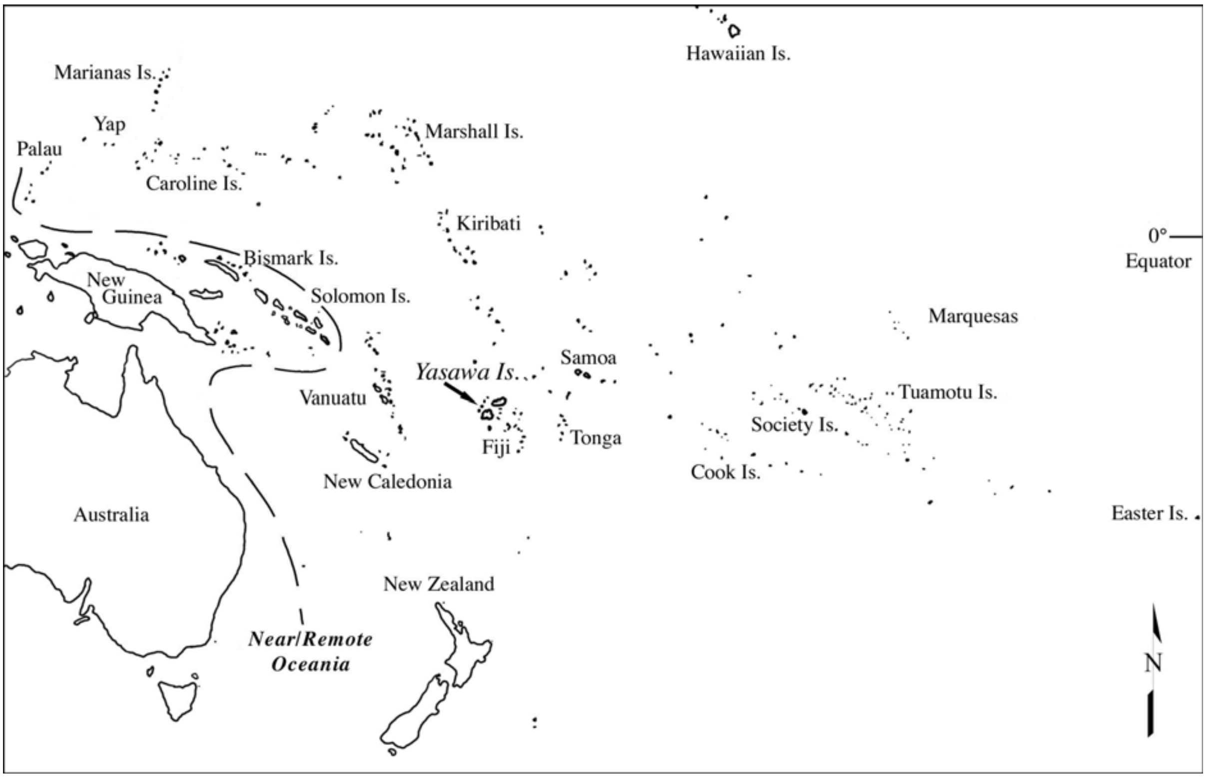

Figure 2. Seriation of seven Yasawa Islands ceramic body sherd assemblages. Assemblage names at left and class names as column heads. Open rectangles represent class frequency within a particular assemblage. Black bars denote error terms calculated at 95% confidence intervals, following Lipo (2001). See Cochrane (2004)for materials and methods.

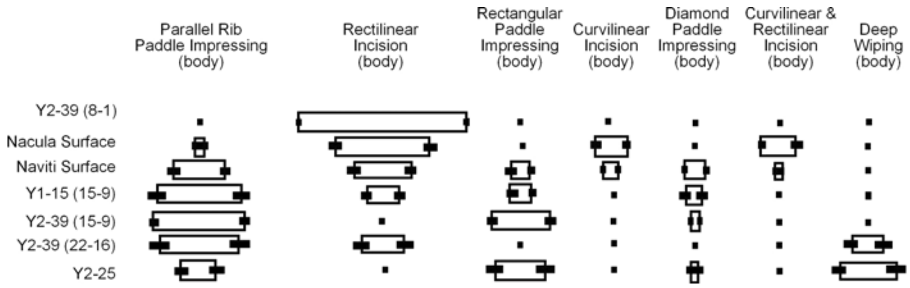

Figure 3. Phylogenetic trees representing hypothesized relationships among 14 Yasawa Islands ceramic rim classes, using two different outgroups. Class definition codes are shown next to each rim illustration. These 50-percent majority-rule consensus trees are generated from 1,974 equally parsimonious trees. Illustrations of classes (interior of vessel to left) convey characteristics of the class only and do not depict actual specimens. Shaded rims are tempered with terrigenous sands. Branch lengths and node positions depict approximate chronological origins and extinctions of classes only. See Cochrane (2004) for full description of materials and methods.

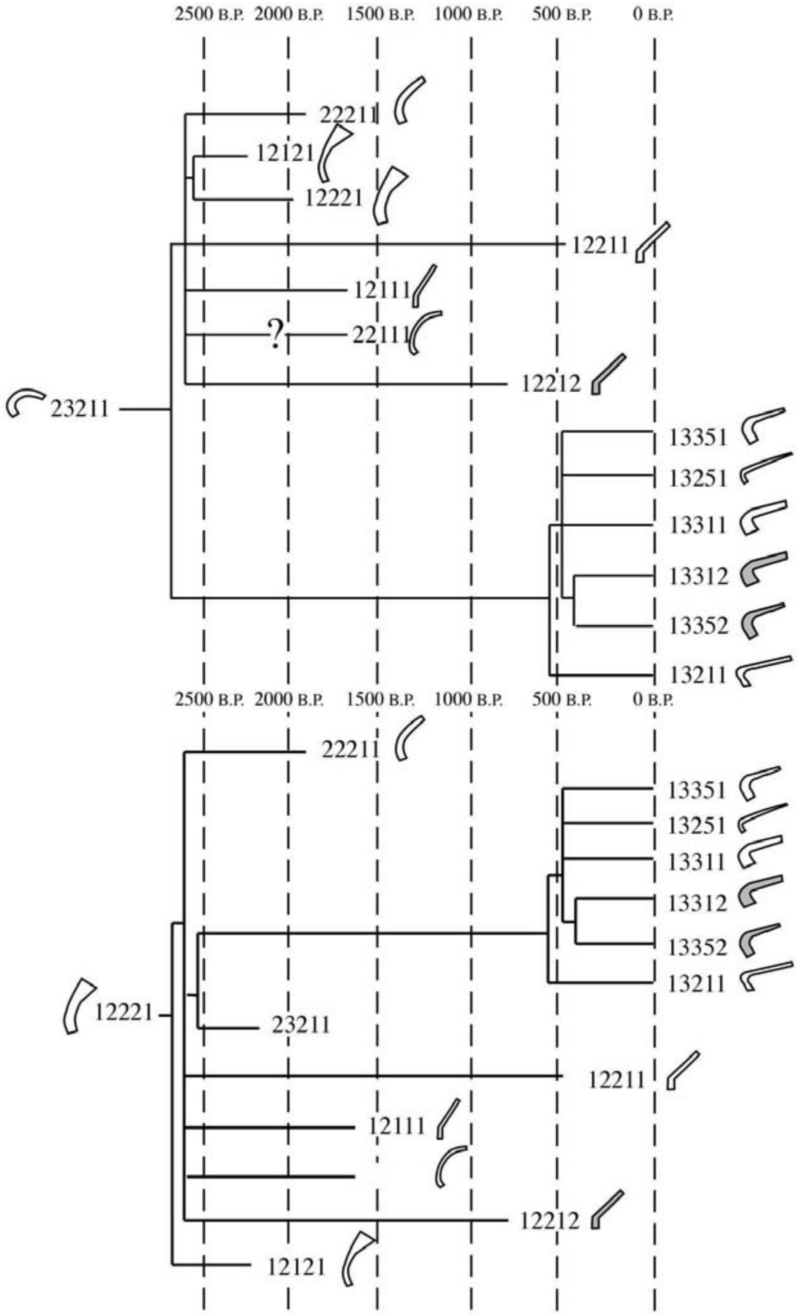

Figure 4. Eerkens and Lipo (2005) figure 1 reproduced. Changes in the value of a metric trait in ten lineages over 400 transmission generations. The average value and the coefficient of

variation of the trait in the ten lineages is also displayed.

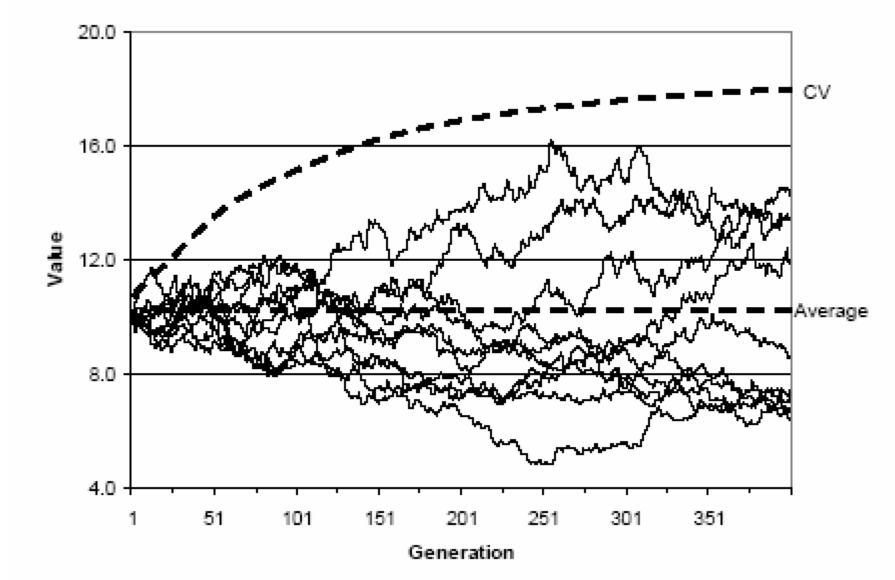

Figure 5. Box plot of mean body sherd thickness (mm) per grouped excavation level at Qaranicagi (test unit 1), basal level to right. Circles are outliers, stars are extreme values. The deepest excavation levels, 17-23 (grouped into two units 18 and 22), contain material dated between 2300-2700 BP; levels 12-14 (grouped into a single unit 13) contains material dated between 920-1270 BP; and levels 2-6 contain materials dating from recent times to 550 BP. Age and depth of sediment are roughly correlated in a linear fashion. The same dates apply to Figures 6 and 7. See Cochrane (2002, 2004) for details of analysis.

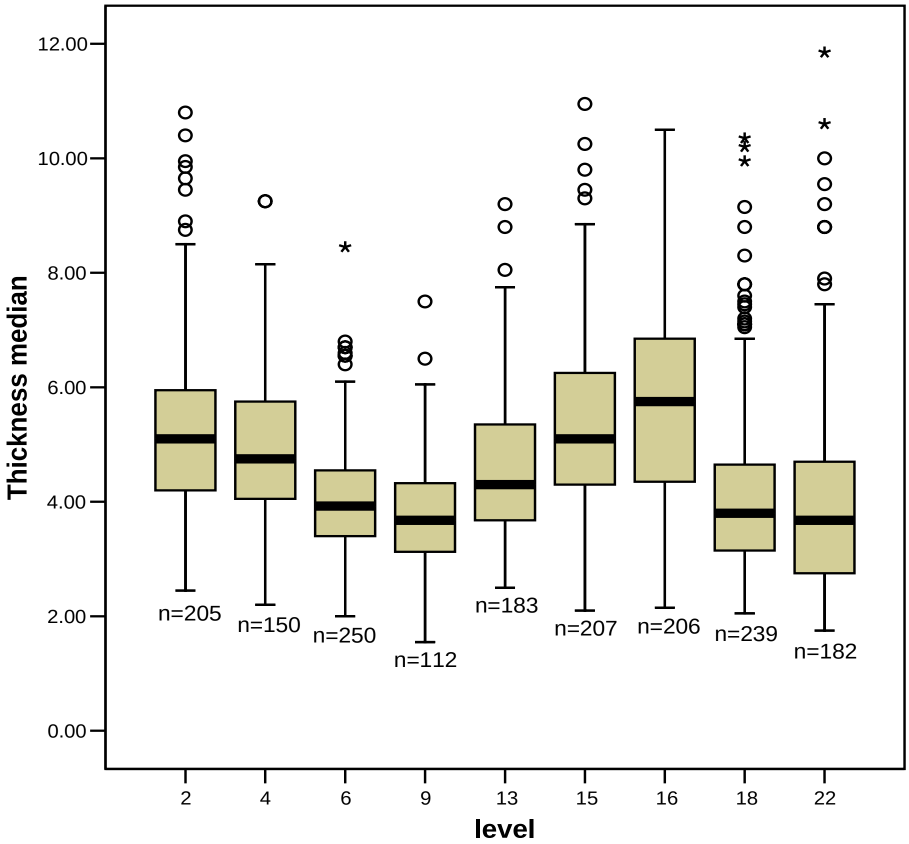

Figure 6. Plot of coefficient of variation (CV) of sherd thickness measures per grouped excavation level at Qaranicagi (test unit 1), basal excavation level to right

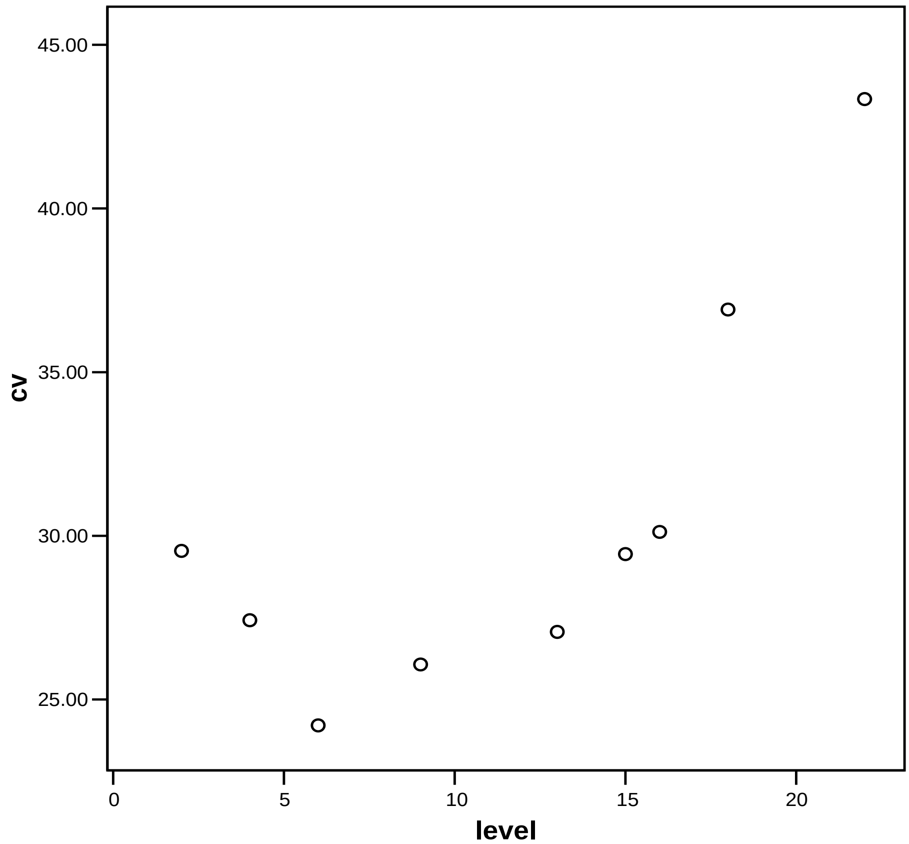

Figure 7. Plot of thickness measurements for sherds (n = 1734) grouped by excavation level at Qaranicagi. Cubic regression line is the best fit to the data (r^2 = 0.083, F = 52.38, p < 0.000), although very little of the variation is explained.