Canoes and cultural evolution

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Over the last 30 years, the idea that the processes producing cultural stability and change are analogous in important respects to those of biological evolution has become increasingly popular. Biological evolution is characterized by changing frequencies of genes in populations through time as a result of such processes as natural selection; likewise, cultural evolution refers to the changing distributions of cultural attributes in populations, which are affected by processes such as natural selection but also by others that have no analogue in genetic evolution. The fundamental, mathematically based theory that justified and spelled out the necessary modifications to standard population genetics theory to make it relevant to culture was laid out by Cavalli-Sforza and Feldman (1) and Boyd and Richerson (2) in the 1980s, on the basis of earlier papers, and Richard Dawkins (3) had already introduced the idea to the popular imagination with his concept of the "meme" as analogous to the gene. In the intervening period, the development of what has come to be called "dual inheritance theory" or "gene–culture coevolution theory" has continued, and it has been accompanied by a slowly growing number of empirical case studies that apply these ideas to understanding patterned variation in cultural data. The article by Rogers and Ehrlich (4) in this issue of PNAS makes a significant contribution to this growing field by showing how different cultural evolutionary processes can be identified and distinguished from one another and how they differentially affect different kinds of cultural traits; it will certainly become a widely cited classic case study, and the dataset of descriptive traits of canoes from different Polynesian groups is likely to become a test bed for future cultural evolutionary studies.

The Processes of Cultural Evolution

Of course, the idea that human culture might usefully be approached by using ideas from biological evolution is not a new one, as the quotation by the French source in 1908 cited by Rogers and Ehrlich (4) indicates, but it has had a checkered history. Only in the late 1970s did this idea's long period of unpopularity begin to end. The extent to which cultural processes may be modeled in evolutionary terms remains disputed, as Rogers and Ehrlich point out [although the way in which cultural entities and processes closely match Darwin's original formulation of the theory of evolution has recently been shown in detail by Mesoudi *et al.* (5)]. In the most general terms, parallel mechanisms for inheritance, mutation, selection, and drift act on culture as they do on genes.

In the case of culture, the inheritance mechanism is social learning: People learn ways to think and act from others. Of course, the routes through which culture is inherited are much more diverse than those for genes (1), and different routes have different consequences for the patterning of cultural change through time. Variation in what is inherited is generated by innovations. These innovations may be unintended copying errors, but they can also be intentional changes, perhaps arising from trial-and-error experimentation, which lead an individual to stop performing a task the way he had previously learned and to start doing it differently, or even to do something different altogether. Whether this novelty will be widely adopted depends on a range of selection and bias mechanisms, many of which have no equivalent in genetic evolution but whose existence and importance have formed the subject of major developments in cultural-evolution theory over the last 30 years (especially refs. 1 and 2). It is important to spell out these mechanisms.

Natural selection can also act on cultural attributes.

Natural selection in the narrowest sense affects humans as it does members of all other species. However, as Rogers and Ehrlich (4) describe, natural selection can also act on cultural attributes, in the sense that those individuals who inherit or acquire certain cultural attributes may have a greater probability of surviving and/or reproducing than those who do not; as a result, those cultural attributes will become increasingly prevalent. For example, it is clear that, in many parts of the world, adopting an agricultural rather than a hunting-and-gathering way of life led to greater reproductive success; as a result, the cultural traits that characterize agriculture spread and, in some cases, subsequently influenced genetic evolution [e.g., the ability to digest lactose (6)]. An analogous process of cultural selection can also operate if individuals with certain cultural traits are more likely to be taken as models for imitation than others, by virtue of those traits, and these individuals in turn become successful models as a result. The traits concerned will become more prevalent even if they have no bearing on reproductive success whatsoever and, indeed, even if they are deleterious to it, because if a trait is passed on in a manner other than by parents to children, there is no reason for its success to depend on the reproductive success of the individuals concerned. For example, if celibate priests are more likely to be influential teachers than other adults and if, as a result of what they teach, their pupils are more likely to be celibate priests and teachers, then the values they teach will increase in frequency in the population.

However, in addition to these selection mechanisms, a number of "bias" processes can affect what is transmitted; these bias processes are factors that affect what and who people try to copy when they are learning from others. Thus, "results bias" refers to the situation in which people look at what other people do (for example, the crops they plant), compare the results with what they are doing themselves, and then change what they do because the other way of doing things seems to be more effective. "Content biases" are affected by features of transmissible phenomena that make them intrinsically more or less memorable for reasons relating to the structure of the mind or the strong reactions they provoke; examples may include be fairy tales or so-called urban myths. "Context biases" are aspects of the context of learning that affect what is transmitted; thus, something may be copied simply because the person initially doing it is prestigious ("prestige bias") or because it is what most people do locally ("conformist bias"). In the latter two cases, whether a particular

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cultural attribute or practice becomes more prevalent in a population has nothing to do with its intrinsic properties but only with the context of learning.

Finally, there is the cultural equivalent of genetic drift. In other words, the frequencies of particular cultural attributes can change for essentially chance reasons not involving any preference for a particular attribute. Who or what you copy may simply be a random choice dependent on who or what you meet.

The "Meme's Eye-View"

As just described, all of these processes focus on the people involved in the processes. This is obviously an extremely important perspective, but it is not the only one. It is also important to look at things from what Dawkins called "the meme's eye-view," the perspective of the cultural attributes themselves. This perspective matters because by and large, as in the case of the canoe attributes analyzed by Rogers and Ehrlich (4), these culturally transmitted features are the data that archaeologists and anthropologists have available. The question then becomes: to what extent is it possible to identify the action of the various cultural evolutionary processes outlined above on the basis of distributions of variation in the (more or less) present, as here, or at various points in the past, a possibility that archaeological data allow? In this field, as in so many others, theoretical modeling has far outstripped empirical investigation.

Even demonstrating that a pattern of contemporary variation, as in the case of present-day ethnographic data, or a pattern of continuity through time, as in the case of archaeological data, results from the operation of an inheritance process as opposed to independent invention in similar conditions is not necessarily straightforward (see, e.g., ref. 7), although we can assume it in the case of the canoes. There are early accounts of the processes of social learning involved in canoe-making, but going further to make inferences about the processes acting on the cultural lineages identified is a lot harder.

Canoe Evolution

What Rogers and Ehrlich (4) have done is make progress in this area by showing that variation that is believed to be under selection is patterned differently from other variation that is believed not to be under selection, or at least not in the same way. It seems to be more conservative and, therefore, under negative selection. Perhaps more surprisingly, they find that there is no correlation at all in the similarities between island groups in terms of functional canoe variation and the similarities based on symbolic variation. One might have expected some correlation, either because both would be affected by the distance between the islands, or because the process of island colonization by groups in canoes would have brought both their functional and their symbolic attributes. The fact that selection appears to have been sufficiently powerful to overwhelm evidence of descent history is extremely interesting and confirms the importance of regarding cultures not as hermetically sealed entities, a bit like species, but as bundles of distinct packages of traits affected by different forces (cf. ref. 8). In distinguishing between these patterns and processes, Rogers and Ehrlich make an important theoretical point against the skeptics: Of course history matters, but it matters through its effects on the operation of general processes, such as selection and drift, just as in the history of life. They also make a significant methodological contribution to work in the field. One direction they rightly note for future work is an investigation of whether or not the pattern of variation in the symbolic canoe traits is the result of drift; as they also point out, if the symbolic traits are being used for, say, identity signaling, then one might expect a deliberate process of diversification. Attempting to characterize cultural drift and identify departures from it has been a major focus of work in recent studies, both for discrete and continuous data (9–11).

Rogers and Ehrlich (4) refer to the process acting on the functional canoe traits as natural selection, and so it is from the perspective of the traits themselves, in that particular traits survive and are copied preferentially as a result of their greater functional effectiveness—something that could in principle be tested experimentally. The results tell us that either there was a very low innovation rate or the vast majority of those innovations that occurred were unsuccessful and therefore short-lived. What they do not do is distinguish between natural selection operating on human agents via cultural traits, and thus on the future frequency of those traits, and results bias, as defined above. In other words, the process could have operated as a result of the makers and users of ineffective canoes drowning more frequently, thus leading to the demise of those designs, whereas groups with better-designed canoes, perhaps different communities, survived and colonized new islands; alternatively, it could have worked through people observing the performance of different canoe designs and preferentially copying those they perceived as more effective. The latter would potentially be far faster and the implied timescale difference could provide a basis for distinguishing between the two processes. This too is work for the future.

As noted earlier, this dataset is destined to be used for all sorts of future cultural evolutionary studies, and not just those that Rogers and Ehrlich (4) themselves mention, but comparisons with interisland group patterning in genetic and linguistic variation as well as cladistic studies that attempt to reconstruct descent relationships and ancestral states. The authors are right to conclude by emphasizing the importance of creating other datasets open to similar analyses. With one or two notable exceptions, the creation of comparable sets of data across time and space has not been the tradition in either anthropology or archaeology, especially in these postmodern times, and it is significant that Rogers and Ehrlich had to go back to an early source to extract their information. If cultural evolutionary studies are to progress, this situation needs to change.

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