Why a Population Genetics Framework is Inappropriate for Cultural Evolution

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Abstract
Although Darwinian models are rampant in the social sciences, social scientists do not face the problem that motivated Darwin’s theory of natural selection: the problem of explaining how lineages evolve despite that any traits they acquire are regularly discarded at the end of the lifetime of the individuals that acquired them. While the rationale for framing culture as an evolutionary process is correct, it does not follow that culture is a Darwinian or selectionist process, or that population genetics and phylogenetics provide viable starting points for modeling cultural change. This paper lays out step-by-step arguments as to why this approach is ill-conceived, focusing on the lack of randomness and lack of a self-assembly code in cultural evolution, and summarizes an alternative approach.

Keywords: acquired traits, cultural evolution, inheritance, natural selection, population genetics, self-other re-organization
Introduction

Darwinian models are rampant in the social sciences. The formal frameworks of population genetics and phylogenetics has been adapted for application in anthropology [1–11], archaeology [12], economics [13–15], and even neuroscience [16,17] and creativity [18–21], and applied to the evolution of languages [22,23]. This is a different project from that of examining how natural selection has shaped the propensity for culture, language, or artifacts; it models cultural change itself as a second Darwinian process. The rationale is that since cultural forms, like biological forms, evolve, i.e., exhibit cumulative, adaptive, open-ended change, culture constitutes a second evolutionary process. This is undoubtedly true; however, cultural Darwinism goes further than the claim that culture evolves; it assumes that the formal framework of population genetics, with appropriate tinkering to accommodate culture-specific phenomena, provides a viable foundation for modeling this second evolutionary process. Though several of the deepest evolutionary thinkers of the 20th Century discouraged the over-zealous application of Darwinian theory [24–26], it has generated hundreds (possibly thousands) of books and scholarly papers, as well as scholarly journals, and is currently thriving.

Though many (e.g., [27,28]) have laid out the similarities and differences between biological and cultural evolution (and there are many of both), the issue addressed here is not simply the ways in which they are similar or different but the extent to which the algorithmic structure of the two processes merits importation of the mathematical framework that has been successfully applied in biology over to culture. The aim of the present paper is to succinctly lay out the argument against this project, step by step, so as to advance to a state where the matter is settled once and for all. Two arguments are presented. The first, the weaker argument, pertains to the issue of randomness. The second pertains to the existence of a self-assembly code. Finally, an alternative evolutionary framework for culture is briefly discussed.

Definitions

Part of the reason it has been difficult to nail down the question of whether or not cultural forms evolve in the same sense as biological forms is that, in drawing parallels between biological and cultural evolution, existing words and concepts are stretched beyond their conventional meanings. While it is true that any redefinition of a term is fine so long as everyone agrees how it is being used, some redefinitions fail to capture the deep structure or essence of their original meaning, which generates misunderstanding. For example, dual inheritance theorists claim that culture is a second form of inheritance [29,30,31,32], despite that the essence of an inherited trait would seem to be that it is transmitted vertically (e.g., from parent to offspring) by way of a self-assembly code (e.g., DNA), and this is not the case with respect to cultural traits [33]. Therefore, to maintain absolute clarity, the key terms used in this paper are defined below, as follows:

**Acquired trait:** a trait obtained during the lifetime of its bearer (e.g., a scar, a tattoo, or a memory of a song) and transmitted horizontally.

**Culture:** extrasomatic adaptations—including behavior and artifacts—that are socially rather than sexually transmitted.

**Darwinian process:** an evolutionary process that works by way of differential selection on the distribution of randomly generated heritable variation in a population over generations.

**Darwinian threshold:** transition from non-Darwinian to Darwinian evolutionary process.

**Evolutionary process:** a process that exhibits cumulative, adaptive, open-ended change.
Inherited trait: a trait (e.g., blood type) that is transmitted vertically (e.g., from parent to offspring) by way of a self-assembly code (e.g., DNA).

Natural selection: evolution of organic (biological) form through a Darwinian process.

Phylogenetic model: a model of the relationships amongst different species (generally pictured as branching or ‘tree-like’) that assumes they evolved through natural selection.

Population genetics: mathematical theory of how organisms evolve through natural selection due to changes in gene frequencies, as laid out by Fisher [34], Wright [35], and Haldane [36].

Selectionist process: another term for ‘Darwinian process’.

Self-assembly code: a set of self-replication instructions.

Self-other Reorganization (SOR): an evolutionary process that involves communally exchanging, self-organizing networks that generate new components through their interactions.

Randomness

A first problem for a selectionist approach to culture is that cultural variation is not randomly generated. Darwinian cultural theorists sometimes concede this point [37,38], but fail to recognize its implications for the assumed validity of a Darwinian framework. To the extent that variation is not randomly generated, the distribution of variants reflects whatever is biasing the generation away from random in the first place, rather than Darwinian selection (i.e., differential selection on the distribution of randomly generated heritable variation in a population over generations). Let us break this argument down step by step.

1. Natural selection is a two-step process, consisting of (i) generation of random variants that differ in fitness, followed by (ii) selection of the fittest variants.

2. The mathematical framework of population genetics assumes that the first step serves to provide variation upon which selection can operate, and that the adaptiveness of the process resides not in the first step (how variants are generated) but the second (how fit variants are selected).

3. To the extent that variants do not differ with respect to fitness, their evolution is attributed not to Darwinian selection but to random genetic drift [34,39]. (Drift has been demonstrated in both human culture [40], and a computational model of cultural evolution [41].)

4. To the extent that variants are not randomly generated, their evolution is attributed not to Darwinian selection but to the nature of this nonrandom generation process.

5. Cultural change is highly non-random; it is strategic and creative, with ideas emerging due to spreading activation and overlap amongst distributed mental representations encoded in associative memory [42–44].

6. Therefore, a Darwinian model is inappropriate to the description of cultural change.

In the cultural Darwinism literature much is written about social learning (obtaining existing information from someone else), and there is some mention of individual learning (obtaining existing information through nonsocial means), but virtually nothing about creativity,
nor reasoning, planning, problem solving, or any of the higher cognitive processes that generate cultural novelty. The highly nonrandom nature of these processes make them difficult to accommodate in their chosen framework. In a paper titled “grand challenges for the study of cultural evolution” [11], absent from among the eight challenges is the challenge of studying the creative processes that fuel cultural evolution. The closest they come is to ask “How are innovations selectively transmitted” and “Do innovations create feedback loops leading to cumulative culture?” It seems that understanding how innovations come about in the first place is more fundamental than knowing how they are “selectively transmitted” or whether they create feedback loops. Without the creative generation of cultural novelty there is no cultural evolution. (This is seen clearly in an agent-based computational model of cultural evolution [41]; when agents never imitate, cultural evolution does occur, albeit slowly, as each agent figures things out on its own, but when agents never create, there is no cultural evolution at all.) Thus, understanding creativity would appear to be the ‘grandest’ challenge of all for cultural evolution research.

The ‘randomness’ argument puts a major dent in the theory that culture evolves through a Darwinian process, but it does not destroy it altogether. It is possible that after cultural variation has been generated by way of nonrandom processes there might still be work for selection to do in winnowing out the very fittest. However, we not turn to the more serious problem, that in cultural evolution there is no self-assembly code.

**Self-assembly Code**

In biological evolution there are two kinds of traits: (1) inherited traits (e.g., blood type), transmitted vertically from parent to offspring by way of genes, and (2) acquired traits (e.g., a tattoo), obtained during an organism’s lifetime, and transmitted horizontally amongst conspecifics. A Darwinian explanation works in biology to the extent that acquired change is negligible relative to inherited change; otherwise the first, which can operate instantaneously, overwhelms the second, which takes generations. We know of no means of avoiding transmission of acquired traits other than by way of a self-assembly code (such as the genetic code), i.e., a set of instructions for how to reproduce. In cultural evolution there is no self-assembly code, and no vertically transmitted inherited traits; all change is acquired. Therefore, cultural evolution is not due to the mechanism Darwin proposed: differential replication of heritable variation in response to selection.

The only response to this argument I am aware of is: “Gabara’s (2004) point concerning the lack of self-assembly codes in cultural entities is, again, well-taken when compared to many biological organisms, but may not hold if we take viruses as our biological exemplar, which similarly cannot self-replicate in the absence of a host, or, as Gabara herself notes, the evolution of early RNA-based life before DNA-based replication mechanisms evolved.” [43] However, this response evades the problem, for the argument is not simply that cultural evolution differs from biological evolution; it is that the assumptions underlying the formal framework developed to describe evolution by natural selection renders it inapplicable to culture. Indeed it is also inapplicable to the description of some aspects of biological evolution, but that should be more reason for concern, not less.

Thus, to help determine whether there is a genuine flaw in the argument, and if so pinpoint what that flaw is, we again break the argument down into steps:

1. In biological evolution there are two kinds of traits: vertically transmitted inherited traits, and horizontally transmitted acquired traits.
2. Acquired traits are discarded from a lineage at the end of every generation.
3. This means that evolution (i.e., cumulative, open-ended, adaptive change) in biological lineages cannot be explained in terms of acquired traits.
4. Therefore, it can only be explained in terms of inherited traits.
5. In biological evolution, inherited traits are not discarded; they are preserved by way of a self-assembly code. The code's low-level information-bearing components must be organized in an orderly manner so they can be parsed into meaningful units; otherwise, the precisely orchestrated process by which it is expressed to generate offspring is disrupted.
6. The population genetics framework was developed to explain change in a system such as this where the slow process of selection for inherited traits over generations is not drowned out by the fast process of acquired change which can take place over milliseconds.
7. Biological evolution is therefore explainable in terms of differential selection on the distribution of randomly generated heritable variation in a population over generations, i.e., natural selection.
8. Since acquired change operates markedly faster than inherited change, to the extent that acquired change is not wiped out at the end of each generation, a population genetics framework will be inappropriate as an explanatory model.
9. In cultural evolution there is no distinction between vertically transmitted inherited traits and horizontally transmitted acquired traits. Since all traits are horizontally transmitted, we may refer to them as cultural acquired traits.
10. Cultural acquired traits are not regularly discarded from cultural lineages at the end of generations.
11. This means that evolution (i.e., cumulative, open-ended, adaptive change) in cultural lineages can be explained in terms of acquired traits.
12. Moreover, in culture there are no horizontally transmitted inherited traits.
13. Therefore, cultural change, unlike biological change, cannot be explained in terms of change in the frequency of inherited; it must be explained entirely in terms of changes to acquired traits.
14. Therefore, there exists no basis upon which to explain cultural evolution in terms of differential selection of inherited traits on the distribution of randomly generated heritable variation in a population over generations, i.e., using a population genetics (Darwinian, or selectionist) framework.

The vastness of the enterprise to frame culture in Darwinian terms would seem to indicate that, to some, one or more of these steps is not self-evident. It is hoped that progress can be made by identifying the step(s) wherein the disagreement lies, for the argument has important implications for the modeling of cultural data. For example, since biological acquired changes are discarded, and since a self-assembly code needs to stay fairly well intact to preserve its self-replication capacity, the joining of bifurcations is rare in biology, and thus a phylogenetic
model is appropriate because it captures the tree-like branching structure. However, since cultural acquired changes are not discarded, and since there is no cultural self-assembly code, the joining of bifurcations is commonplace in culture and the cognitive processes that underlie it, and thus the structure is network-like rather than the tree-like [45]. This difference has been demonstrated mathematically using split-decomposition graphs [46,47]. Dress and colleagues showed that while biological data generate branching graphs, reanalysis of data from a psychological experiment in which people were asked to estimate the subjective distance between colours gives a very different structure [48]. This difference in the deep structure of biological data, and cultural data such as languages, concepts, and artifacts that arise from human cognition, is why phylogenetic approaches to culture are misguided.

**Self-Other Reorganization (SOR): An Alternative Approach to Cultural Evolution**

The above analysis precludes a selectionist but not an evolutionary framework for culture. Evolution can occur in the absence of Darwinian selection, and the importance of non-Darwinian processes in evolution is increasingly recognized [49–51]. Research on the origin of life suggests that early life consisted of autocatalytic protocells that evolved through a non-Darwinian process, and natural selection emerged later from this more haphazard ancestral evolutionary process [52–61]. This non-Darwinian process requires (1) a self-organizing network of components that generate new components through their interactions, (2) the network should be able to reconstitute another like itself through haphazard (not code-driven) duplication of components, and (3) interaction amongst networks. This process can be referred to as Self-Other Reorganization (SOR) because it involves an interplay between self-organized internal restructuring and communal exchange amongst autocatalytic structures. Like Darwinian evolution it has mechanisms for preserving continuity and for introducing novelty, but unlike Darwinian evolution it is a low-fidelity Lamarckian process. The distinction between these two evolutionary processes is summarized in Table One.

|                          | **Darwinian Selection** | **Self-other Re-organization (SOR)** |
|--------------------------|-------------------------|-------------------------------------|
| **Unit of self-replication** | Organism                | Self-organizing autocatalytic network |
| **Mechanism for preserving continuity** | Reproduction (vertical transmission), proofreading enzymes, etc. | Communal exchange (horizontal transmission) |
| **Generation of novelty** | Mutation, recombination | Creativity and innovation, transmission error |
| **Self-assembly code** | DNA or RNA               | None                                |
| **High fidelity**       | Yes                     | No                                  |
| **Transmission of acquired traits** | No                      | Yes                                 |
| **Type**                | Darwinian               | Lamarckian (by some standards)      |
| **Evolution processes it can explain** | Biological             | Early life; horizontal gene transfer, culture |
Table One: Summary of the distinction between evolution through Darwinian selection and evolution through Self-Other Reorganization.

Vetsigian et al. showed that to cross what they refer to as the Darwinian threshold from a non-Darwinian to a Darwinian evolutionary process required the emergence of a self-assembly code [52]. There is no evidence that cultural evolution has crossed this threshold, and indeed cultural evolution does not possess the signature characteristic of having crossed this threshold: lack of transmission of acquired traits. It has been proposed that, as did early life, culture evolves through SOR [62–66] (though sometimes the process has been referred to as not SOR but ‘communal exchange’) . Here, the self-organizing networks are not protocells exchanging catalytic molecules, but minds exchanging ideas. As parents and others share knowledge with children, an integrated understanding of the world takes shape in their minds, and they become creative contributors to cultural evolution. It has been noted that a tension exists between cultural evolution theory and the literature on human nature [67]. Because SOR is not incompatible with the transmission of acquired traits, and because it recognizes the integrated, ‘self-mending’ nature of an individual mind, it provides a natural means of reconciling cultural evolution and human nature.

Conclusions
The problem Darwin faced was the problem of explaining how lineages evolve despite that any changes they acquire are lost from the lineage at the end of the lifetime of the individuals (i.e., at the micro-level) that acquired them. Darwin’s solution was to come up with a population-level (macro) explanation. He reasoned that although acquired traits are discarded, inherited traits are retained, so evolution can be explained in terms of preferential selection for those inherited traits that confer fitness benefits on their bearers. However, cultural evolution researchers do not face the problem that motivated Darwin’s solution—i.e., the problem of explaining how evolution takes place despite the inevitable discarding of acquired traits—because cultural acquired traits are not discarded. Thus, while the rationale for framing culture as an evolutionary process is correct, it does not follow that culture is a Darwinian or selectionist process, or that population genetics and phylogenetics provide viable starting points for modeling cultural change. Psychologists use the term mental set to refer to the persistent use of problem-solving strategies that worked in past even when these strategies are not appropriate to the new problem. It appears that the persistent application of a Darwinian or selection framework to cultural evolution, despite that the conditions that make that framework applicable in biology are not present with respect to culture, may be an instance of mental set. This paper has laid out step-by-step arguments as to why such a project is ill-conceived, and pointed to an alternative approach.

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