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Can evolution be directional without being teleological?

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ABSTRACT

Convergent evolution reveals to us that the number of possibilities available for contingent events is limited, that historically contingent evolution is constrained to occur within a finite number of limited pathways, and that contingent evolution is thus probabilistic and predictable. That is, the phenomenon of convergence proves that truly contingent evolutionary processes can repeatedly produce the same, or very similar, organic designs in nature and that evolution is directional in these cases. For this reason it is argued in this paper that evolution can be directional without being teleological, and that the dichotomy that evolution must either be directionless and unpredictable or directional and predetermined (teleological) is false.

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1. The false dichotomy of contingency versus teleology in evolution

The York University biologist Jan Sapp (2012) argues that a false dichotomy has been erected in the construction of the evolutionary contingency-versus-directionality debate, namely "the false dichotomy between the factors of contingency and chance on one hand and directed evolution based on supernatural forces on the other. In the history of evolutionary biology, it is chance, the struggle for existence, and contingency that have always been on the side of evolution; goal-driven physiological change was always on the side of supernaturalism and the antievolution movement. This dichotomy has been maintained by an ongoing conflict between scientists and creationists" (Sapp, 2012, 694). Why is this dichotomy false? It is false because evolution can be directional without being teleological (McGhee, 2011, 272–73).

The false dichotomy that evolution must either be directionless or unpredictable (a possibility that is mislabeled "contingent" in the false dichotomy) or directional and predetermined (teleological) repeatedly appears in the many arguments of Stephen Jay Gould, the Harvard paleontologist and best-known evolutionary essayist of the late twentieth century. For example, Gould (1989) frames this false dichotomy as the "question of questions" in his argument against the views of the early twentieth-century paleontologist Charles Doolittle Walcott: "ultimately, the question of questions boils down to the placement of the boundary between predictability under invariant law and the multifarious possibilities of historical contingency. Traditionalists like Walcott would place the boundary so low that all major patterns of life's history fall above the line into the realm of predictability (and, for him, direct manifestation of divine intentions). But I envision a boundary sitting so high that almost every interesting event in life's history falls into the realm of contingency" (Gould, 1989, 290); that is, into the realm of unpredictability.

The teleological endpoint in the false dichotomy certainly exists as such. That is, under a teleological view evolution is directional and predetermined—teleology is defined as "the fact or quality of being directed toward a definite end or having an ultimate purpose, especially as attributed to natural processes."[1]

But what about the opposite endpoint in the false dichotomy, the evolutionary "factors of contingency and chance" referred to by Sapp (2012, 694)? In his article in this issue John Beatty differentiates between "contingent *per se*," in which a given evolutionary event was a matter of chance (such as a genetic mutation), and

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[1] *Webster's New World Dictionary*, 2nd college ed., s.v. "teleology."

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"contingent *upon*," in which a given evolutionary event depended upon the occurrence of a prior event (such as the evolution of an ancestor). Does contingency in either of these two senses really require that evolution be directionless and unpredictable? At first glance it might seem so, as in our current understanding biological evolution is generally modeled to be the outcome of the interaction of chance (random genetic mutations) and uncertain conditions (changing environmental habitats in nature); that is, evolution is the product of genetic mutations and natural selection, where genetic mutations are seen as the source of new biological variation and natural selection is the mechanism sorting the biological variants in terms of their differential adaptations to different environmental conditions. In fact, both of these components of the standard model of evolution can produce directional trends. First, it is a well-known mathematical fact that random processes, chance processes, can product directional trends. The best known of these are Markov chains. A Markov process produces "a sequence of events such that each event is partly dependent on the outcomes of preceding events and partly dependent on a random process acting at the time of the event itself" (Raup, 1977b, 62). Computer simulations using Markov chains are thus an ideal way to explore temporal processes that are both contingent *upon* (Raup's "each event is partly dependent on the outcomes of preceding events") and contingent *per se* (Raup's "partly dependent on a random process acting at the time of the event itself"), and can be used to simulate random walks in a single evolving phylogenetic lineage or random evolutionary branching in multiple phylogenetic lineages (Raup, 1977a, 1977b).

In the field of evolutionary paleobiology itself, the University of Chicago theoretician David M. Raup ran computer simulations of chance (contingent *per se*) and historically contingent changes (contingent *upon*) in the morphologies of hypothetically evolving species. David Sepkoski has provided an account of these studies in his article in the issue. Raup's early work (Raup & Gould, 1974) demonstrated that random simulations can produce: (1) apparent directional trends in morphological change in evolving lineages, (2) apparent correlation between combinations of morphological traits within an evolving lineage, (3) variation between rates of morphological change in different evolving lineages, (4) apparent "terminal" overspecialization within an evolving lineage, and (5) clumping of randomly evolved morphologies within a theoretical morphospace of the hypothetical spectrum of forms that potentially could be evolved. Prior to Raup's random simulations, all of these phenomena were thought to be produced only by deterministic evolutionary processes. Thus Raup's computer simulations demonstrated that chance processes (contingent *per se*) and historically contingent processes (contingent *upon*) could produce directional trends; that is, truly contingent evolution (in both senses of contingent) is not necessarily a directionless process.

Second, natural selection is a deterministic process, not a random one. Wilson and Bossert (1971, 40) point out that natural selection is a deterministic process in that it involves "directions and rates that can be measured in populations and used to predict specific outcomes" and that only evolution via genetic drift is a stochastic process in which only probabilities of outcomes, not a specific outcome, may be predicted. The mechanism of natural selection differentially sorts biological variants in terms of their differential adaptations to environmental conditions, and differentially preserves the variants with better states of adaptation. Thus natural selection is a directional process, one in which the frequency of organisms with better states of adaptation increases with time in evolving populations (given constancy in the environmental conditions producing the selection).

The fact that Charles Darwin's concept of natural selection was both deterministic and directional has led Humboldt State University biologist John Reiss (2009, 140) to argue that the very concept itself is teleological: "Darwin introduced a teleological determinism into the heart of his theory. This teleology is expressed in two related conceptions: (1) that evolution is a process going from a less-adapted to a better-adapted state and (2) that natural selection is a deterministic force, or agent, that directs the evolutionary process toward this better-adapted state." That is, Reiss considers the very idea of adaptive improvement via natural selection in evolution to be teleological because improvement is a directional concept and any hint of directionality in evolution is teleological. Thus the false dichotomy that directionality in evolution must be teleological because contingent evolution is directionless lies at the heart of Reiss's argument.

Is it teleological that water flows in the downhill direction? That it goes from a state of higher potential energy to a state of lower potential energy under the influence of the deterministic force of gravity? Philosophers may argue whether that phenomenon is teleological or not, but in science it is an empirical observation, an established fact. Why then would it be teleological if organisms evolve in the direction of better states of adaptation under the deterministic force of natural selection?

2. How contingent evolution gives rise to predictable directionality: nature has limited choice

Contingent evolution (in both senses) can be directional with being teleological, but can the direction of evolution be *predictable* without being teleological? This question addresses the second part of the false dichotomy that evolution is either directionless or unpredictable (a possibility that is mislabeled "contingent" in the false dichotomy) or directional and predetermined (teleological).

Certainly any natural process that is "directed toward a definite end or having an ultimate purpose" can be considered to be teleological.[1] Thus Reiss further objects to the concept of natural selection as a "deterministic force, or agent, that directs the evolutionary process" towards a better-adapted state because this "better-adapted state" appears to be a goal, and that a goal-directed process is teleological (Reiss, 2009, 140).

Is it teleological that water flows in rivers toward the future "goal" of reaching a sea or lake? The flow of water is mindless, and water has no goal in sight, but nevertheless it will reach its lowest possible potential energy state under the deterministic force of gravity, which means that it will wind up in a sea or lake. And we can confidently predict that flowing water will wind up in a sea or lake although we may not be able to predict *which* sea or lake without a great deal of additional information about the geography and topography of the landscape across which the water is flowing.

Natural selection is a deterministic process and thus, theoretically, one should be able to predict its outcome if one knows the magnitudes of all of the variables at work in the process (Wilson & Bossert, 1971). In actual practice that is a very difficult task indeed. In addition, the element of randomness does enter the equation of natural selection in that the state of the environmental conditions producing the natural selection mechanism (of sorting biological variants in terms of their differential adaptations to those environmental conditions) are uncertain. That is, we may be able to calculate the probabilities that environmental conditions will change in this direction or the other, but we cannot do so with absolute certainty. We are all familiar with the uncertainties involved with weather forecasting where predicted future weather conditions are given in probabilities, not certainties.

It is at this point that the empirical pattern of actual evolution on Earth helps us out tremendously: much of evolution is *convergent*. Convergent evolution reveals to us that the number of evolutionary pathways available to life is not endless, but is instead quite limited.

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