Discussion:
Indeterminism, Probability and Randomness in Evolutionary Theory

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David Stamos (2001) is not alone in attributing to Graves/Horan/Rosenberg (1999) (hereafter GHR) together, and to Horan (1994), and Rosenberg (1994) separately, the view that “the processes of evolutionary biology are fundamentally deterministic and that the statistical character of evolutionary biology is explained by epistemological rather than ontological considerations. (2001, p. 1)” Others have made objections to GHR similar to his. But Stamos’ paper is the best expression of these objections yet to appear. His paper explores one important way in which, using Brandon and Carson’s (1996) expression, genuine quantum mechanical indeterminacy can “percolate up” into biological processes, by effecting mutations with adaptational upshots. On the basis of this exploration, he concludes that GHR are mistaken in alleging that the probabilities of the theory of natural selection are epistemic, that quantum-percolation undermines claims about the autonomy of biology from physical science, and that Brandon and Carson’s (1996) identification of quantum effects as the source of the theory of natural selection’s probabilities is vindicated after all.

By contrast to Stamos, Bruce Glymour (2001) attributes to GHR the claim that “indeterministic evolutionary phenomena are reliably predictable by a deterministic evolutionary theory” (2001, p. 15) and the claim that “the assumption of indeterminism is a methodological disaster because it is only by assuming that evolutionary behavior is deterministic that we come to search for the causes of such behavior.” In part to refute these claims, Glymour advances another source of indeterminism in evolution, random foraging strategies which make for differences in fitness, in which genuinely indeterministic quantum events or perhaps thermodynamically stochastic brain events also percolate up to make for fitness differences.

Although I cannot speak for my fellow authors, I believe that much of what Glymour and Stamos say about the quantum-mechanical sources of mutation, and random predation-search and their

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implications for biological processes is correct, and that for this reason biology is indeed indeterministic in at least some of its most important fundamental processes. The fact that in advancing their argument to this effect, Stamos and Glymour make some significant mistakes about the view defended in GHR, would not by itself warrant a rejoinder to their papers. What does justify it is that first, despite the information about quantum effects and random search strategies they deploy, and the cogency of some of the inferences made from them, Stamos and Glymour still fails to rightly identify the source of the statistical character of the theory of natural selection, and second, I now believe that neither did GHR, together or separately. This discussion note therefore provides a convenient opportunity to address this question again.

1. A preliminary distinction. There is a distinctions it is important to honor in pursuing this debate: we need to be careful about distinguishing theories from the world they describe, and not to identify without argument indeterminism in the world with probabilities in theories. A theory can be statistical even though the world is deterministic, and vice versa. Even if the world is deterministic some of our true and correct theories about the world may turn out to be statistical. The best and at the same time most troubling example of this fact is the second law of thermodynamics, which would be both true and statistical even were the world thoroughly deterministic. If the world is fundamentally indeterministic, our true statistical theories may not be statistical as a consequence of the fundamental indeterminism of the world, but may be a consequence of some other fact about the world. Again, the second law of thermodynamics serves as an example. Moreover, a theory may be deterministic and a true description of an indeterministic world. For example, Newtonian mechanics suitably restricted to the description of the behavior of macroscopic objects over finite periods of time only, will be instantiated by the histories of many possible worlds—including the actual world—in which (indeterministic) quantum mechanics obtains, but in which the probabilities of violation of Newton’s laws by macroscopic objects are so low that there is not a single actual violation in the amount of time taken up by the whole history of the possible world in question.

That the actual world is such a world is what GHR had in mind in claiming that quantum

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phenomena *asymptotically* approach determinism in almost all biologically significant processes (GHR, p. 144, 145). To keep firmly in mind this distinction between a probabilistic theory and a probabilistic world, GHR labeled such a world ‘indeterministic’, restricting ‘probabilistic’ to qualify theories alone.

So, the question which GHR, Horan and Rosenberg addressed is what sort of probabilities figure in the theory of natural selection, recognizing that a) in the actual world, there are quantum mechanical “pure probabilistic propensities”, b) there are thermodynamic probabilities as well, which are neither quantum mechanical pure probabilistic propensities nor yet epistemic probabilities either, and c) the existence and nature of probabilities in the *world* does not thereby fix the existence and nature of probabilities in all true *theories* of the world.

Like Brandon and Carson (1996) before him, Stamos fails to honor this distinction. From his quite correct claim that in the case of mutations quantum mechanical percolation occurs, Stamos infers directly and illicitly that therefore the probabilities of the theory of natural selection must be the pure probabilistic propensities of quantum mechanics. Glymour honors the distinction. Indeed it is crucial to his mistaken attribution to GHR that a deterministic theory can predict indeterministic phenomena. We were entirely silent on the predictive employment of the theory.

### 2. Stamos’ and Glymour’s Contributions

GHR criticized a number of thought-experiments advanced by Brandon and Carson (1996) designed to show how quantum effects might “percolate” up in biological processes with sufficient effects to make the evolutionary trajectories of such populations genuinely indeterministic. I stand by the criticism GHR lodged against these thought-experiments, including in particular the case in which a quantum indeterministic event shifts a classically characterized dominant allele into its recessive partner. Aside from GHR’s criticisms of this thought-experiment Stamos notes, there is the further matter that the dominant/recessive distinction is not one easy to make in terms of molecular genetics.

However, Stamos’ provides more than a thought-experiment for the claim that an other sort of percolation is possible. He provides a detailed discussion of how variation can arise through the placement of the wrong nucleotide in a DNA molecule during replication, resulting in a copying error.

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that constitutes a point mutation. There is percolation in this case owing to the fact that the resulting base-pair mismatches are, as Stamos’ review suggests, overwhelmingly likely to be the products of quantum indeterministic effects.

The quantum indeterministic character of mutations is of the greatest consequence for Darwinism. Darwin himself was a determinist about the causes of variation. He wrote in On the Origin [p. 131], “I have hitherto sometimes spoken as if the variations ... had been due to chance. This of course is a wholly inaccurate expression, but it serves to acknowledge plainly our ignorance of the cause of each particular variation”. About one thing Darwin was certain: that variations do not appear as a result of the benefits (or for that matter the costs) which they subsequently confer on organisms, as measured by enhanced (or reduced) reproductive fitness. But aside from this negative claim, Darwin had no positive account of the causes of variation. The subsequent discovery of mutation and ultimately the indeterministic character of point mutations in nucleic acid sequences, provides the positive account of the indeterministic source of variation the theory of natural selection requires, if it is to exclude any role for a designing agency in the evolution of diversity, complexity and adaptation.

As Stamos notes at the end of this paper, such an exclusion is crucial for the defense of Darwinism against theological or metaphysical compromise. Stamos quotes Monod’s (1971, p. 112-113) claim: “chance alone is the source of every innovation, of all the creation in the biosphere. Pure chance, absolutely free but blind, at the very root of the stupendous edifice of evolution. It is today the sole conceivable hypothesis, the only one that squares with observed and tested fact.” Without real randomness, it is always open to exponents of teleological explanation—whether theistic or otherwise—to hypothesize a force which arranges mutations in order to produce some pre-ordained outcome that looks for all the world like natural selection over random variation. With real randomness, no such reconciliation of Darwinism and design is logically possible.

Glymour invokes a source of randomness in the determination of fitness that GHR did not envision.¹ If a predator’s optimal search pattern is a really random one, and if such optimality is attainable, then there will be fitness differences between predators that hinge on differences in their random search patterns, and these differences in fitness will therefore themselves be as random as the

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random patterns which give rise to them. Assume that such search patterns are really random, either because they are produced by quantum indeterministic processes (or by thermodynamic noise—an alternative Glymour briefly notes, (2001), p. 12) in the nervous system. Between them Stamos’ mutational source for mutational indeterminism and Glymour’s neural source for stochastic effects in fitness provide strong arguments for the claim that evolution, the process, is indeterministic. Do they show that the nature of evolutionary probabilities in the theory must be these indeterministic processes?

3. Quantum Randomness Leaves the Nature of Evolutionary Probabilities Open. Matters are however not settled so easily in respect of the nature and sources of probability in the theory of natural selection. Recall the preliminary distinction above. It shows that whether the world is indeterministic or not does not settle the matter of whether a true and correct theory about the world must be statistical or not, and that even if the world is indeterministic, the probabilities in our best theories about the world need not themselves reflect this indeterminism but may have another source. Arguing from the preliminary distinction GHR, Rosenberg, and Horan, all held that the indeterminancy which quantum mechanics rightly attributes to the world, need not be the source of the probabilities of the theory of natural selection.

One reason for this conclusion reflects the fact that the theory of natural selection embodies other probabilistic elements beside a commitment to variation resulting from random mutations. Among these other probabilistic elements of the theory there are the characterization of fitness in terms of probabilistically expected rates of reproduction, and the principle of natural selection [PNS] itself: “If \( a \) is fitter than \( b \) in environment \( E \), then (probably) \( a \) will out-reproduce \( b \) in \( E \)” Notice that both the definition of fitness as a probabilistically expected number of off-spring, and the principle of natural selection were propositions Darwin and Darwinians asserted long before the advent of quantum mechanics, or the realization that its indeterminism accounted for variation via the randomness of mutations. Therefore, either the meaning of the term ‘probability’ as it figures in the theory of natural selection changed at the moment the relevance for point mutations of quantum indeterminism was realized, or alternatively, quantum indeterminism cannot be the source of the these probabilities. GHR do not quote without approval of author alexrose@duke.edu
GHR advanced several arguments for the claim that these probabilities had to be epistemic. I believe that this claim remains correct for the probabilities that figure in the probabilistic measures that characterize fitness. The so-called probabilistic propensity definition of fitness has in recent years been shown not to define fitness so much as provide a set of alternative “operational definitions” (thus definitions-*manque*) that enable us to apply a much more schematically defined predicate, ‘fitness’ to actual cases of natural selection. The problems facing the original definition of fitness as a probabilistic expectation to leave off spring are that a) in many low resource environments sometimes it is evolutionarily advantageous to leave a smaller number of high quality off-spring that a larger number of lower-quality ones, b) sometimes as between two organisms with the same probabilistically expected number of off-spring, one will be fitter than the other owing to the variance in probabilistically expected alternatives, c) sometimes the measure relevant for fitness is the probabilistically expected number of grand off-spring, or great grand off-spring, etc. These insights are due to Beatty and Finsen (1989), and Beatty (1992), following Gillespie (1975). What they shows is that the simple and widely applicable measure of fitness in terms of probabilistically expected numbers of off-spring is just that, a measure, not a definition, indeed a measure appropriate only in some and not all evolutionary contexts. Since fitness is supervenient on a vast disjunction of organism/environment packages, it can only be defined (if at all) in terms of notions like ‘adaptednesss” , or “design problem solution”. More important, the probabilities in which fitness is measured will be Bayesian inferences from prior probabilities updated by new demographic evidence, and will therefore be subjective or epistemic. The concept of fitness is thus probabilistic without introducing quantum indeterminism to evolution.

However, GHR, Horan and Rosenberg’s claim that epistemic probabilities *exhaust* the statistical character of the theory of natural selection was, I now believe, mistaken in one crucial respect. For the way in which the principle of natural selection invokes the notion of probability cannot be understood either epistemically or in terms of probabilistic propensities of the sort quantum mechanics trades in. The notion of probability that the principle of natural selection invokes can only be understood as the kind of probability to which thermodynamics adverts.

The principle of natural selection [PNS] states that “If *a* is fitter than *b* in environment *E*, then...

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hen (probably) \( a \) will out-reproduce \( b \) in \( E \). This principle must be interpreted in terms that make it a nomological truth. But this requirement excludes interpretations of the probabilities it invokes other than the one invoked in the probabilistic second law of thermodynamics. If the probability invoked in the PNS is the same epistemic one that figures in fitness measures, the PNS turns out to be the tautologous claim that “if \( a \) has a higher expected reproductive rate than \( b \) then \( a \) will be expected to out reproduce \( b \)”. If the relevant notion of probability is actual frequencies, then we know the PNS is false, especially when the number of organisms and generations involved is small enough for drift to have a role. The probabilities here cannot be quantum mechanical, because the PNS will obtain in a perfectly deterministic world (indeed, Darwin thought the world in which the PNS obtains is a perfectly deterministic world), and in any case, the probabilities relevant to the interaction of macroscopic biological entities with their environments are too small to be causally relevant, given the length of time involved. This leaves only long run relative frequencies, i.e. the sort of probabilities that the second law of thermodynamics invokes as the relevant source of the probabilistic character of the PNS. Thus GHR were mistaken to limit the source of evolutionary theory’s probabilities to the epistemic. (I suspect that such thermodynamic probabilities, in “ion channels” as Glymour has it, are the real source of the randomness in search behavior that Glymour reports, if the behavior is truly random. But the theory of natural selection would embody such probabilities even if random foraging were not selected for.)

In one respect this a very satisfactory solution to the problem of the nature of evolutionary probabilities. It begins with a state-space within which any possible distribution of evolutionarily competing systems can be located, and any evolutionary trajectory can be plotted; then for each point in this space, it expresses the ratio of points at which fitter systems descendants are more numerous to the total number of points describing all possible demographic distributions accessible from the given point. Since this ratio is always higher than .5, the PNS obtains. Mutatis mutandis for the second law of thermodynamics: It begins with a state-space within which any possible trajectory of distributions of objects can be found; then for each point in this space, it expresses the ratio of entropy increasing points to total physically accessible points. Since this ratio is always higher than .5, the second law of thermodynamics obtains (whether this world is a quantum mechanically indeterministic or Newtonian mechanistic one).

In another respect this analysis of evolutionary probabilities as equivalent to thermodynamic ones, is deeply unsatisfactory. For the nature of thermodynamic probability is itself not well unders
tood. There is a long standing conviction that the second law is reducible to or explainable without remainder in terms of the distribution of mechanical properties in a purely deterministic system. This is one reason thermodynamic probabilities are not pure (that is, ungrounded) probabilistic propensities. Thermodynamic probabilities are grounded in the manifest or occurrent mechanical properties of physical systems, and we anticipate a reduction of these dispositional properties to occurrent ones. The pure probabilistic propensities of quantum mechanics are ungrounded in more basic manifest properties because there are no more basic properties than the quantum mechanical ones to which they might be reduced.

The obstacle to our anticipated reduction of thermodynamic probabilities to mechanical properties is simple enough to state: since the number of points in the state space of thermodynamics is indefinitely large, the relevant ratios of increased entropy states to total states cannot be computed. No philosopher or physicist from J. Willard Gibbs to Larry Sklar has been able to effect the reduction.

It is tempting to conclude from this failure that thermodynamic probabilities are sui generis, a distinct sort of probability that is neither epistemic nor the result of indeterminism. But this is simply to label the problem of what the second law’s probability consists in.

Mutatis mutandis for the probabilities of the PNS. The reduction of the probabilistic PNS to a theory of disaggregated organism/environment interactions cannot be effected, even if the organism/environment interactions are deterministic. And the reason is the same as in the thermodynamic case: the ratio of states of increased fitness to total demographically possible states cannot be computed because the number of points in evolutionary state space is too large. Thus, to insist that the PNS invokes the same probability as that of thermodynamics is, I think, a correct insight, but is only the first step to facing the real problem of what evolutionary probability consists in.

4. Conclusion. Stamos speculates “that the real debate between Brandon and Carson on the one hand and [GHR] on the other is about the autonomy of biology from physics...It is clear that these authors [GHR] wish to exclude from biological processes the causes of mutation, whatever they might be.” [p. 17-8]. Any one familiar with Rosenberg’s work will find the charge that I seek to underwrite the autonomy of biology from physics ironical. Any one who reads GHR will recognize that we had no wish do not quote without approval of author alexrose@duke.edu
to exclude the causes of mutation from the realm of the biological, even had we the power to do so. What we wished to do was reveal the sources of probability in our best theory of the biological. We may not have succeeded, but we honored the requirement on any account of evolutionary theory’s commitment to probabilities, that it distinguish the world from true theories of the world, and avoid facile inferences from properties of the former to features of the latter.

Glymour concludes that “any complete and correct evolutionary theory must be probabilistic” (2001, p. 20). This of course is something GHR never doubted. Still less, pace Glymour (2001, p. 21) did they assert that evolutionary biologist need assume the truth of determinism. What they asserted was that the world is indeterministic, but that fact alone cannot by itself go very far towards explaining the statistical character of evolutionary theory. I suspect in the end Stamos and Glymour agree with GHR on this conclusion.

References


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Footnotes

1. Though the point had been made to me in personal communication by Frederic Bouchard.

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