J. Non-Equilib. Thermodyn., Ahead of Print
DOI 10.1515/JNETDY.2011.028

Comment and reply on Annila and Salthe's "Physical foundations of evolutionary theory": Confusing the 2nd law and 4th law, and other issues

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In their recent paper [1], Annila and Salthe state their main claim in the first line of their abstract asserting that "(t)he theory of evolution by natural selection is herein subsumed by the 2nd law of thermodynamics."

There are some significant problems with this and other claims in their paper that I will address briefly in these short comments. The first and central problem is that what the paper actually says is not as it claims that evolution by natural selection is subsumed by the 2nd law, but rather by the law of maximum entropy production (that the rate is maximized). This underscores the further problem that while I agree with the authors that this idea is true, it is not at all new or original to the authors or their paper.

Starting with the central problem then, while the authors' summary sentence claims subsumption under the 2nd law, by the last sentence of the abstract we see it is not actually the 2nd law but it is "(t)he principle of maximal energy dispersal, equivalent to the maximal rate of entropy production, (that) gives rise to the ... regularities found in nature." Their erroneous conflation becomes explicit later when they write that "(t)he 2nd law," as they mean it in this paper, "is conceptually simple. It says: energy flows from heights to lows as soon as possible. This imperative for the extremum is also known as the maximum entropy production principle" (p. 307), and cite me (Swenson [6]) and three others, for the principle. Indeed, their statement of the principle, "energy flows ... fast as possible" is a paraphrase of what I first proposed, and elaborated further with colleagues more than two decades ago first as the "principle of maximum entropy production" (MEP) and then as the "law of maximum entropy production" (LMEP) (e.g., [3, 7, 8, 10, 13]) as follows:

> a system will select the path or assembly of paths that minimizes the potential or maximizes the entropy at the fastest rate given the constraints

But this (what they call the "maximum entropy production principle," but I will call the "law of maximum entropy production" consistent with the title of the paper of mine they cite for the principle [6], or "LMEP" [3]) is not the 2nd law. The 2nd law says entropy increases in all natural processes but *says nothing about path selection or rates*, viz., what paths out of otherwise available paths a system will take to get to equilibrium or maximize the entropy. LMEP is an entirely different law answering just what the 2nd law does not. When authors thus say that natural selection is subsumed by the 2nd law, the claim is clearly erroneous since what they mean by their own definition is LMEP or the "4th law," as it has more recently been called (e.g., [4, 5, 11]) and not the 2nd. Redefining the 2nd law as LMEP does not make the two equivalent in fact.

While authors' claim to have subsumed natural selection with the 2nd law is thus clearly false, I agree completely with their actual claim of subsumption by LMEP. As noted above, however, herein lies the problem with this as a new or original idea. My agreement should not be surprising since my colleagues and I have been arguing LMEP and its subsumption of natural selection for more than two decades (e.g., [13], and for review see [12]). Indeed, it was in the context of seeking to address the physical foundations of evolutionary theory that the law of maximum entropy production (LMEP) was formulated and then proposed as the "physical selection principle" that accounted for natural selection as a special case.

Among other errors authors make is their claim to have physicalized information under LMEP. To support this they cite a recent paper in which one of them (Annila) is a co-author [2] where it says: "the maximum entropy production principle allows one to address physical information in evolution" (p. 2156) and then cites my 1991 paper with Michael Turvey [13] where we did just that. We made the point that the fundamental striving for information or "knowledge" about the world is about locating potentials (gradients or energy densities) to degrade and thereby expand the dissipative dimensions of the system. Authors take the point generally, but their assertion that there is no principled demarcation between living and "inanimate systems" (p. 311), underscores that this by itself is hardly sufficient for physicalizing information (semantics *or* syntactics).

Do authors really think there is no principled or discernible difference between the end-directed behavior of water flowing down a slope, or heat flowing down a heat gradient, and a bacterium moving *up* a chemical gradient or *up* a light gradient in search of food [9]? Information can be physicalized from first principles under a general evolutionary theory based on path selection following from LMEP (or the "4th law"), but certainly not

by simply waving it away or denying the distinction. Discussion of further details on this point is beyond the scope of the brief comments here, but they are available for interested readers in the references provided.

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Received August 21, 2011; accepted October 19, 2011.

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