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Ecological complexity in the Rosennean framework

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ABSTRACT

Rosen's mathematical framing of the nature of complexity can be summarized qualitatively as simple systems are reducible to models that correspond precisely to nature while complex systems are not reducible in this manner. We use two examples, *Tribolium* laboratory populations and the pest control system in coffee agroecosystems to argue that either a very simple system or a very complicated system cannot be reduced to a series of simple systems and thus conform to Rosennean complexity. We further suggest that alternative framings, specifically dialectical complexity, may be equally useful.

Centers for the study of complex systems have emerged at intellectual centers over the world, incorporating fields ranging from physics to psychology, from economics to sociology, with ecology being one of the most affected disciplines. The corpus of study includes an eclectic collection of usually mathematical frameworks, loosely intersecting with one another. When one speaks of ecological complexity, it seems that this eclectic collection is what is spoken of. Rosennean complexity appears to encompass something different in that it attempts to articulate a simple core that provides us with a deep understanding of the complexity inherent in nature's systems. Here we review two themes that are representative of the collection of topics that most researchers in ecology regard as complexity, and suggest that, if there is insight to be gleaned from the Rosennean complexity framing, it lies at the intersection of these two themes.

At a deep level Rosen, and later several of his followers, use the mathematical framing of category theory to make deep statements about the nature of complexity, what has been referred to as Rosennean complexity. We do not intend to interrogate that mathematical core. Rather, a variety of metaphors and more generally qualitative statements that have been made in the name of Rosennean complexity will be our focus. For example, in an interview for Belgian television, in answer to the question "What is complexity?" Rosen stated:

"Complexity is really recognized by the failure of all our attempts to deal simply with these systems. Simplicity is easier to define. I define a system to be simple if it has certain properties and anything else is a system that isn't simple; I call 'complex'. Simplicity is one of the things we inherited from physics; a philosophy of science: [*that says*] all systems can be broken up in a certain canonical set of ways and all systems are built up out of pieces that arise from such decompositions, again in a certain canonical set of ways. So, a system is simple if you can take it apart in a familiar fashion or put it together from pieces in a familiar fashion. That's what basically it means for a system to be simple. The whole idea behind physics was that all systems were simple. And that's the way science progresses, by finding the right pieces and the right ways of putting the pieces back together." (http://www.people.vcu.edu/~mikuleck/rsntpe.html)

This is a non-mathematical summary of a dense system of mathematical arguments that Rosen developed, first under the watchful eye of Rasheveski, and then extensively elaborated, and further refined and expanded by such philosopher/mathematicians as A. H. Louie and M. Nadin, among others. Our intent here is to query some of the independent literature on ecological complexity and ask whether current literature that speaks of complexity in ecology could have been or can in the future be informed by Rosen's notions. We find, in formal treatments in the ecological and complex systems literature certain qualitative parallels.

A key element of Rosennean complexity seems to be the comparison between a natural system and the model of that system. Characterizing simple systems, Rosen notes:

"The ingredients of this ultimate description, by their very nature, are themselves devoid of internal structure; their only

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changeable aspects are their relative positions and velocities. Given the forces acting between them, as Laplace noted long ago, everything that happens in the external world is in principle predictable and understandable. From this perspective, everything is determined: there are no mysteries, no surprises, no errors, no questions, and no information." (Rosen, 1986: pg 187).

Simple systems can, in principle, be completely modeled, and even if they are composed of many components, if each of the components can be completely modeled, the overall system is non-complex. For sake of argument one might claim that physics is fundamentally a simple system, which would allow us to compare it to biology which, in Rosen's view, is a complex system. As he notes:

"One way of describing this with a single word is to assert that organisms are *complex*. This word is not well defined, but it does connote several things. One of these is that complexity is a system property, no different from any other property. Another is that the *degree* to which a system is complex can be specified by a number, or set of numbers. . . . On a more empirical level, however, complexity is recognized differently, and characterized differently. If a system surprises us, or does something we have not predicted, or responds in a way we have not anticipated; if it makes errors; if it exhibits emergence of unexpected novelties of behavior, we also say that the system is complex. In short, complex systems are those which behave counter intuitively." (Rosen, 1986: pg 186 [italics in original].

We take these characterizations to mean that complex systems are not reducible to a collection of simple systems – perhaps a useful qualitative working definition of Rosennean complexity. We think a quick personal note may be relevant here. One of us (JV) was giving a presentation to a mixed group of physicists and biologists a few years ago and the topic was interspecific competition whereby the particular model being presented led to some surprising conclusions that did not correspond to standard ecological interpretations. The audience was queried as to what might be the explanation of the deviation of model from the obvious reality, and the biologists responded with many possible explanations. But then one of the physicists responded by asking what the question was in the first place. Did not the equations say that? And if they did, there was nothing to explain, the equations WERE the reality. We relate this episode because we think it speaks to the utility of what Rosen was getting at. In physics it is normally expected that, once one gets it "right", one's equations will indeed represent reality and the study of the equations is almost identical with the study of reality. Rosen would suggest, and we would agree, that ecology deals with much more complicated issues, and ecologists are forced to theorize in a different style. Our theories (usually in the form of mathematical equations) are thought to be only rough approximations to reality, devices to help us think through what we intuitively understand to be complexity. In this sense Rosennean complexity at its foundation seems to force us to the conclusion that ecological systems are "Rosennean complex," since the philosophy of model-building, in both its philosophical and practical sense is arguably distinct from physics (Levins, 1966; Weisberg, 2006).

Part of what Rosen seems to have been attempting was to categorize those systems that generated "surprise." Having settled on a model of the system, and being sure of the definitions of both variables and parameters, when sudden deviation of model and system emerges, the non-complex mind seeks to decompose the system into smaller parts. The process then repeats itself and, ultimately, all the parts can be represented by a model that is, in a deep sense, sure to represent the system. One can then study the model and be assured that one is at the same time studying the system. Yet, a complex system, no matter how subdivided it becomes, will ultimately have behaviors that emerge from its existence that will deviate from the model that was a simple connection of its subcomponents. It is this emergence that is at the core of the idea of Rosennean complexity. Thus, even though it may appear that ecology is not the place to try and formalize Rosen's notions to help us sort out what is complex and what's not, if we take this soft view of the idea, we may ask questions about "surprise" in ecological systems, focusing on relatively standard and accepted models and the surprises they provide, either with post acceptance exploration or comparison with real world data.

What we believe to be closely related to what Rosen was proposing is what we refer to as "dialectical complexity." In their discussion of dialectics more generally, Levins and Lewontin note:

"It is not that the whole is more than the sum of its parts. But that the parts acquire new properties. But as the parts acquire properties by being together, they impart to the whole new properties, which are reflected in changes in the parts, and so on. Parts and wholes evolve in consequence of their relationship, and the relationship itself evolves. These are the properties of things we call dialectical: that one thing cannot exist without the other, that one acquires its properties from its relation to the other, that the properties of both evolve as a consequence of their interpenetration.“ (Levins and Lewontin, 1985: pg 3).

As we argue more extensively elsewhere (Vandeemeer and Perfecto, 2017), the general field of complex systems as it is currently developing, seems very closely related to this idea of dialectical complexity, bring up the possibility that there are significant overlaps between dialectical complexity and Rosennean complexity, at least as applied to ecology. Here we explore complexity, mainly from the Rosennean point of view, since this issue is devoted to that subject.

In particular, we present two examples. The first is one in which it would seem we had discovered a simple system in Rosen's sense, in biology, yet more cautious look found a major discrepancy between model and system, the population dynamics of the flour beetle, *Tribolium*. Furthermore, it seems clear that breaking the model down further would not help, but in the end elaborating it in a completely different direction was the key to resolving the contradiction between model and data. The second example extends from our own research and is effectively the inverse of the first example. We know, from observation and experiment that the pest control system in the coffee agroecosystem in Mexico is complicated, and we suspect it is complex. We offer it as an example where the biological system is indeed composed of subsystems, yet its complete integrity depends on the multiple connections among the subsystems, making the test of Turing compatibility difficult to even contemplate since every coupling represents yet another subsystem. With even a first approximation of subdivision we encounter unresolvable contradictions.

1. Simple biological system, with no simple model

Our first example is from population growth data of the small beetle *Tribolium castaneum*. A relatively simple nonlinear mathematical model does extremely well at predicting the population sizes of the beetles in these small containers. For example, one form of the model predicts that the population should oscillate between two densities, and that between those two densities it should experience an unstable point. In the real population data based on an experiment done in 1980, the population numbers over time seemed, at first, odd, as shown in Fig. 1. However, with the aid of the model that predicted a two level attractor (with populations jumping from high values to low values every two