# A Natural History of Equations

**Self-organization in Complex Ecosystems.** Ricard C. Solé and Jordi Bascompte. Monographs in Population Biology 42. Princeton University Press, Princeton, NJ, 2006. 392 pp. $45.00 (ISBN 0691070407 paper).

I am going to be critical in this review, so in case it gets lost in what follows, let me say at the outset that *Self-organization in Complex Ecosystems* is an excellent book, and could well be the very best of its type. With clarity and persuasion, this book discusses the mathematics of emergent processes by importing from physics the tools of statistical mechanics.

It starts with an appealing overview of complexity in ecological systems. This whole school of complexity science makes much of nonlinearity, and that is where the authors go next, giving a good account of chaos theory. As a general issue in complexity and emergence, nonlinearity becomes worth recognizing as the scope of a discourse is expanded with a move up in scale to include what before was part of the context. Approximately linear relationships have room to show nonlinearity, which redefines the situation. That happens in nature as well as in equations, and causes the relative homogeneity seen inside entities to give way to heterogeneity between the inside and the outside of an emergent structure. Solé and Bascompte, however, are more interested in the mathematics of all this than in its appearance in nature. In fairness, the authors do not completely neglect the common sense and actual experience we have of material emergence.

This book has been much influenced by findings in landscape ecology, so spatial self-organization appears as an early chapter. The account of fractals is broad ranging and thorough. One of the book's strengths is that it raises important issues, such as habitat loss. But as a limitation, it is less about real-time loss than about the mathematics surrounding that issue, and then only a certain sort of mathematics. For a book with "self-organization" and "complex" in its title, there are some surprising holes in the literature cited, caused by the narrow view of what is relevant.

For example, the complexity and the emergence that happens as a space is filled with pixels were worked out by Gardner and his colleagues at Oak Ridge National Laboratory in the 1980s, but only more recent accounts are cited in this book. Oak Ridge did, after all, put down the foundations of this stuff, but the authors of this book belong to another invisible college. Solé and Bascompte appear to belong to the network theory, digraph school of ecology, so it is natural that their book should contain a large section on food web theory. Even after their good framing of all that, I persist in my misgivings that the problem of data collection and bounding food web networks has never been adequately addressed. I still ask if food web theory actually is about something material as opposed to something merely mathematical. But at least the mathematics here is laid out as well as it can be. The book ends with a very interesting section on complexity in macroevolution, where there are some new and substantial ideas.

Emergence has become the hallmark of complexity, and its underlying process of self-organization has become something of a buzzword. It goes back to what Schrödinger called "order from disorder" in his book *What Is Life?* (1944). There is a certain irony in Schrödinger's work being one of the critical foundations of this whole thrust toward emergence and self-organization. Schrödinger's position is now identified as safe and orthodox (order from order is genes, and order from disorder is the Prigoginian, far-from-equilibrium emergence discussed by Solé and Bascompte). But Schrödinger was radical in his day, and remains so. His bottom line in 1944 was that we had no physics adequate to address biology, and that shortcoming still applies today (Rosen 2000). In biology, one simply cannot get away with the assumption that the system is closed and close to equilibrium, a foundational assumption in physics so that the bookkeeping works. These authors want to import ideas from physics into ecology, but their chaotic strange attractors are equilibrium structures despite their nonlinearity and elaborate behavior. Schrödinger would probably have some misgivings about where his ideas on emergence have led Solé and Bascompte.

There is a tension in biology between the thermodynamics of life and the way in which it is coded. Self-organization applies when structure appears independent of any coded expectation. There is no plan for an emergent structure such as a whirlpool—it merely happens when a head of water sits above a hole. But in biological systems there is an interplay between thermodynamic emergence, which creates structure spontaneously, and coding, which stabilizes that emergence. Subatomic particles are divided from atoms over vast scale differences. In biology, coding stabilizes the small differences between biological levels, such as organelles and cells, allowing the dense hierarchies in biological structure to exist. Significance, with meaning and functionality, derives from coding. *Self-organization in Complex Ecosystems* never touches that coding, and so in a sense it misses exactly half the point of complexity. The book never gets further than the thermodynamics of the situation. Even when Solé and Bascompte do discuss evolution, it is in the context of flux leading to some elaborate expression of central tendency, not the development of meaningful function. That said, the book does go a lot further than most in exploring micro- and macroevolutionary fluxes, but it remains stuck in thermodynamic expressions of nature.

Where is C. S. Holling in the references? He is not even cited for type I, II, and III equations, although he is mentioned by name for them in the body of the text. How can one cover far-from-equilibrium systems without citing the classic 1994 article by Schneider and Kay, "Life as a Manifestation of the Second