

By Jean Matthews

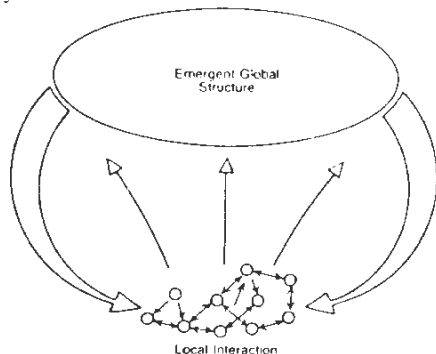
Complexity: Life at the Edge of Chaos, by Roger Lewin (Macmillan, 1992) is a spell-binding journey through the fields and laboratories of those who are pushing toward a set of rules that some day may provide a grand unification of the life sciences. Their various approaches to these elusive rules have landed them at the core of the current struggle to redefine evolution—or at least to rewrite the Darwinian version of it.

Lewin's story begins in Chaco Canyon, NM, the center almost a millennium ago of the complex, sophisticated Anasazi culture. Although it disappeared like steam from a boiling kettle, the Anasazis' economic, political, and religious web, which covered more than a hundred thousand square miles, is referred to by today's archaeologists as the Chaco phenomenon.

From that bleak, arid terrain on the Colorado Plateau, the story moves to consideration of how such complex systems as the Anasazi culture might have arisen from a simple set of organizational rules. For someone who has read James Gleick's absorbing best-seller, *Chaos*, it may be hard to imagine a more enthralling journey through the frontiers of scientific discovery, but Lewin has provided a worthy sequel.

The theory of chaos is described early on in Lewin's book by Chris Langton of the Santa Fe Institute as a subset of complexity "in that you are dealing with nonlinear dynamical systems." In the case of chaos, he explains, a few things are interacting, producing tremendously divergent behavior—what he calls "deterministic chaos." It looks random, he says, but it's not, because it results from "often quite simple equations that you can specify." In the case of complexity, Langton continues, "interactions in a dynamical system give you an emergent global order, with a whole set of fascinating properties" leading to what the Complexity theorists call "emergence."

Langton's view of emergence in complex systems looks like this:



The interaction of the components at the bottom of the diagram give rise to properties that could not have been predicted from what you know of the component parts. And the emergent properties then feed back, to influence the behavior of the individual interactors that produced them.

Lewin then jumps back to the beginning of the story—in the early 1960s when a bright young scholar, Stuart Kauffman (now of the University of Pennsylvania) began playing around very seriously with random Boolean networks. Kauffman's ignorance of mathematics served him well; he accomplished something no knowledgeable mathematician would have attempted. By incredible luck, early in his computer runs, his modest network stumbled into an emergence of order of a sort. His first thought was "Oh my God. I've found something profound," and he told Lewin "I still think so. It's the crystallization of order out of massively disordered systems. It's order for free." This "accident," born of intuition and nurtured by diligence and luck, is one of the first building blocks in an edifice that has arisen from similarly serendipitous starting points in a scientific landscape ranging from geology and biology to archaeology and evolution. The names of contributors to this new scientific adventure include Murray Gell-Mann, Warren McCulloch, John Maynard Smith, Per Bak, James Lovelock, Stuart Pimm, Richard Dawkins, John Cowan, Edward O. Wilson, Stephen Jay Gould, and Brian Goodwin.

Lewin describes the debate between Gould and Goodwin as to whether complexity and the edge of chaos reveal a sort of progress in the random flow of Darwinian selection. When Goodwin is challenged about his definition of the idea of "quality" in an organism, he replies that by "quality" he means "the organism as the cause and effect of itself, its own intrinsic order and organization." Goodwin asks us to think of organisms as the result of a biological attractor—a sort of whirlpool in the sea of a complex dynamical system. Then, he says, "you begin to approach what I mean by quality."

In addition to the gripping story of how complexity theory has grown, by leaps of faith and intuition simultaneously in different disciplines and farflung geographic locations, I found most compelling the idea of Darwinian adaptation being only the surface manifestation of evolution, riding on the deeper structure of rules that seem to govern nonlinear dynamical systems of all kinds, throughout the universe.

The "emergenists" (as the seekers of these rules have been called) seem to have reached a tentative definition of "progress" in the evolution of systems: the ability to process more and more information. What should interest readers of *Park Science* is the possible role of this new theory as a push toward a holistic view of nature. The Santa Fe Institute people talk of "self-organization in complex systems, the emergence of patterns in evolutionary models that mimic patterns in nature, and the idea that living systems, as complex dynamical systems, are driven to these same patterns. They are saying there is a deep theory to the order of nature."

When they are accused of straying from mechanics and "looking for the meaning of life," they reply (in the words of Goodwin): "We're not looking for the meaning of life, more the meaning *in* life, the generation of order, the generation of pattern, the quality of the organism."

Kauffman adds: "Pure Darwinism leaves you without an explanation of the generation of biological form. In the Darwinian view, organisms are just cobbled-together products of random mutation and natural selection, mindlessly following adaptation first in one direction, then the other. I find that deeply unsatisfying and I don't think that's because I want there to be some purpose in evolution." Kauffman would reformulate Darwinian theory to include self-organization. "We have no theory in chemistry, physics, biology, or beyond, that marries self-organization and selection. To do so, as I think we must, brings a new view of life." In effect, he says, it extends self-organization from the realm of physics, where it's accepted, into biology, where it is still viewed as mystical at best and heretical at worst.

Lewin is a Ph.D. in biochemistry from the University of Liverpool. His most recent book, *Bones of Contention*, has been named the U.K.'s top science book for a general audience, besting both Stephen Hawking's *A Brief History of Time*, and James Gleick's *Chaos*. In May 1989, Lewin received the first Lewis Thomas Award for Excellence in Communicating Life Science.

From Complexity

"... if the concept of the edge of chaos does indeed translate from computer models to the real world, as Stu Kauffman, Chris Langton, and others firmly believe it will, then there will be nothing trivial about it at all. Stu's coevolutionary model systems get

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themselves to the edge of chaos, and so too do Stuart Pimm's and Jim Drake's ecological models. No one can say yet whether individual ecosystems do the same thing, but the data from mass extinctions at least suggest that, globally, they do. 'That's a powerful message of a powerful intrinsic dynamic,' said Chris. 'Systems poised at the edge of chaos achieve exquisite control, and I believe you see that right the way up to Gaia.'

"If it's true that, for instance, ecological communities move toward the edge of chaos, where novel properties emerge (such as foodwebs and the ability of a long-established community to resist invasion by alien species), then it seems legitimate to talk about such communities as real systems. It

may even be legitimate to think of them as behaving and evolving as a whole, analogous with the superorganism concept that Ed Wilson talked about in connection with social insect colonies. Coevolving communities act in concert as a result of the dynamics of the system; they do so as a result of individuals within the community myopically optimizing their own ends and not as collective agreement toward a common goal; and the communities really do come to know their world in a way that was quite unpredictable before the science of Complexity began to illuminate that world."

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Troubling complexities is the title of an article by I. Peterson in the Sept. 5, 1992 issue of *Science News* (p. 157). In it, Peterson states:

In studies of the dynamics of biological systems, researchers face the dilemma of determining from experimental data whether observed variations represent random fluctuations or the chaotic state of a deterministic system. If they can demonstrate that the system is chaotic rather than random, they have a better chance of developing a strategy to understand and control this erratic behavior.

Peterson quotes Leon M. Glass of McGill University in Montreal: "Complex aperiodic rhythms that are observed in natural systems might be due to deterministic chaos, random 'noise,' or some combination of the two different mechanisms. Thus, the interpretation of the dynamical basis of complex aperiodic rhythms in natural systems is a difficult and hotly debated topic."