Book Review

Complexity: the Emerging Science at the Edge of Order and Chaos

M. Mitchell Waldrop (1992)

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M. Mitchell Waldrop's book, "Complexity: the Emerging Science at the Edge of Order and Chaos" is the story of a set of individuals and a set of ideas, all coming together in the mid-1980's to form the nascent science of complexity. While the nexus for these events is the formation of the Santa Fe Institute, Waldrop adopts a formula of describing each of the major players in terms of their personal intellectual journeys from early thinking about such concepts as adaptation and emergence to their recognition as top thinkers of our time in the area of complexity. The similarities and differences between these independent, developing lines of thinking are a major part of the charm and appeal of the book. As the Santa Fe Institute is formed in 1984, it becomes the glue to bring these thinkers together and encourage a highly creating and dynamic dialog that Waldrop argues is advancing thinking about complexity much more rapidly than would otherwise be possible.

As Waldrop makes clear in his opening pages, the science of complexity is still very new and wide-ranging. Yet Waldrop's aim is to establish complexity as an up-and-coming and entirely legitimate new branch of scientific thinking that moves beyond the linear, reductionist approach that has dominated scientific thought since the days of Newton. Complexity, the theory goes, manifests itself in "complex adaptive systems", which are made up of many independent agents who interact and adapt to each other and to their environment, producing the phenomenon of emergence -- a system behaving as more than the sum of its parts. Perhaps the most compelling evidence that Waldrop can muster of the promise of complexity is the sheer variety of examples of complex adaptive systems, from such diverse fields as economics, physics, computer science and biology.

Waldrop's tone is serious, but he retains a sense of balance. He manages to put an optimistic glow on the potential of complexity to address a series of key issues of human existence and the nature of the universe, while still acknowledging that complexity is not yet ready to rewrite all of human scientific thinking. He issues a warning of sorts about the implications of complex systems, poised "on the edge of chaos", but he does so without being alarmist. The possibility of dramatic change, analogous to massive extinctions evident in the fossil record, implies that the utility of complexity theory to the human race may be much greater than mere satisfaction of intellectual curiosity. If, as many of the thinkers at Santa Fe would argue, complexity theory holds out the possibility of recognizing patterns of behavior of complex systems, just as meteorologists have developed an understanding of various weather patterns, then the resulting knowledge may help the human race achieve its own survival.

What is evolving at the Santa Fe Institute is a common language and a framework for thinking about complexity that is enabling experts to establish connections between a multitude of disciplines. In the words of Stuart Kaufman, "the very existence of a common framework is reassuring, in the sense that most of the blind men at least seem to have their hands on the same elephant." Economists thinking beyond equilibrium in the marketplace are finding common ground with biologists deciphering the underlying mechanisms of evolution. The dynamic nature of adaptation and emergence are sometimes reminiscent of chaos, a condition without order or form. Yet what is compelling is that structure and self-organization continue to emerge everywhere one

looks -- in the formation of stars and planets, in the evolution of more complex species, and in the self-correcting influences on the economy provided by market forces.

One of the important insights emerging from complexity theory is the concept of complex systems poised at the "edge of chaos" in a zone between rigid stability and chaotic turbulence. Computer modeling has become a mainstay in the search for patterns of complexity, and Waldrop goes into great detail to describe the formulation of several different models, all leading to the same observation of a balance point between order and chaos where complex systems come alive and produce emergent order.

Existence of all this order at the edge of chaos would seem to fly in the face of the second law of thermodynamics, which declares an inexorable process of decay from order into chaos. Waldrop argues that one of the important directions of complexity theory is toward a reformulation of the second law, to take into account the structure and trend toward greater, rather than less, complexity in the universe. Why isn't the universe just a random mess of unrelated particles? How is human consciousness even possible? Some other forces, inherent in the nature of the universe, are at work. Given more time and thought, the many insights that are forming regarding complexity may converge into a real theory which, Waldrop argues, has the potential to shed light on these forces.

While the potential of the Santa Fe Institute is still unfolding, a new realm of economics has been established, in large part around the theories postulated by Brian Arthur. This body of thought goes beyond the rational actor and supply/demand

equilibrium that has embodied neoclassical economic theory since the days of Adam Smith. Human agents are not all-knowing and do not always make profit maximizing decisions, nor is the economy always in a frozen state of equilibrium. Complexity theory offers a window into the phenomenon of adaptive behavior of agents and emergent properties, such as the apparent personality of the marketplace. Workshops, journal articles and visiting scholars led to the spreading of this new way of thinking, resulting in one of the more substantive achievements of the Santa Fe Institute, the legitimization of this new approach to economics.

As Waldrop summarizes the conditions at the Santa Fe Institute as of 1992, the founder, George Cowan is stepping down, leaving a vibrant, productive culture in place at the institute for his successor. As Ed Knapp prepared to take the helm, the institute had a solid financial backing in place from the National Science Foundation, the Department of Energy, and many other donors. But more importantly, it has a culture that has eschewed departments or permanent staff in favor of a more dynamic, innovative approach in which many thinkers from diverse fields rotate in and out of the institute on temporary assignments, bringing their contributions to the discussion and carrying back a deeper understanding of the implications of complexity theory. Waldrop argues that this paradigm excels as a fertile ground for the development of a new body of thought, to a greater degree than would be possible in a relatively static institutional academic setting such as a university. The multitude of disciplines represented at Santa Fe is resulting in a reintegration of many fragments of scientific thought, combining the rigor of the physical sciences with the vision of the social scientists.

Waldrop combines an engrossing style with a rich presentation of many fascinating concepts arising from this new thinking about complexity. One is left with abundant evidence that something is going on here that has the promise to be very important. Waldrop is aggressive in his advocacy of this new body of theory, but he does a reasonable job of recognizing its limits and its current state of evolving maturity. At times his prose verges on an almost religious zeal for the insights that are emerging, but Waldrop quickly brings things back down to earth. In this way, he seems to capture some of the mood of exuberance that prevails at the Santa Fe Institute while still emphasizing its legitimacy to a scientific community that puts a high value on rigor and discipline. Waldrop makes it clear that we are still missing a precise understanding of how complex systems operate. But according to Brian Arthur, "this is the next major task in science for the next 50 to 100 years...we're finally beginning to recover from Newton."