The Complexity Sciences: A Scientific Revolution & Renaissance "Comparable to the Discovery of Language & Mathematics"

Quotations compiled by Alder Stone (www.stonesmap.com)

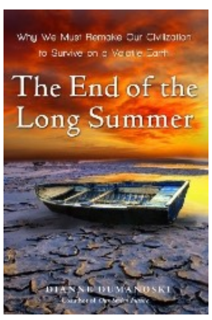
Introduction

One of the — if not THE — greatest challenges I've faced during my nearly 20 years as a free-lance educator teaching the principles of complexity sciences applied to living systems — cells, organisms, ecosystems and the whole Earth — and human organizations has been to explain my answer to the question, "So what?". That is, why should anyone outside of the halls of academia devote any time at all to learning about complexity, let alone spending over 20 hours learning the basic principles in my video course, Complexity 101, then potentially years in advanced study with me as dozens have? That's a reasonable and even important question, especially for those with university degrees in the sciences (except the complexity sciences).

My short answer is that complexity changes how we understand ***everything*** at all size scales, from chemistry to cosmology — nature, Earth, life, organizations, societies, economies, political systems and climate — in fundamental and profound ways, a shift from the current cultural views of linear, predictable and controllable machines to self-organizing, evolving, non-linear — and therefore — unpredictable and uncontrollable wholes. It is a night-to-day shift in worldview as important as political, economic and legal changes as we grappled with our existential planetary crisis. Those changes are necessary, but not sufficient. A new worldview or cultural map is equally necessary if we are to achieve true sustainability and long term survival on a volatile Earth.

But this is not just my opinion, which emerged during 30 years of studying and teaching complexity, beginning almost immediately after finishing my PhD in evolutionary ecology in 1990 (at UNM). Many, if not most, researchers of and writers about complexity hold opinions similar to mine about the profound change from a worldview rooted in mechanistic reductionism to one rooted in complexity; in fact, they helped me understand this. Complexity is a new kind of science, a revolution that is inspiring a renaissance in our collective human worldview that is necessary for the emergence of new cultural maps to guide us into the future. In these quotes from some of my main texts and references, the authors explain my thesis in their own words.

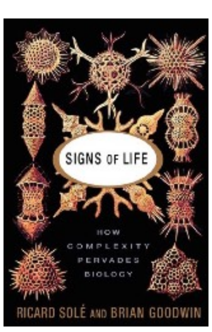
Dianne Dumanoski, *The End of the Long Summer: Why We Must Remake Civilization to Survive on a Volatile Earth*, 2009 —



"The modern view [17th - 20th centuries] of world as machine is falling away, undermined by challenges arising within science itself, as well as by real world events. The living organisms in nature — evolving, non-linear, open systems that stay alive by taking in energy and resources from the surrounding environment — cannot be adequately understood by means of the simple, universal laws sought by the classical sciences based on mechanical philosophy [that began with Isaac Newton and Rene Descartes]. Indeed, even nonliving matter is anything but the passive, inert lumps of stuff imagined by atomistic mechanical philosophy. When matter, such as sand or water, is part of such a system with energy flowing through it, astonishing things begin to happen. Matter begins to organize itself [called self-organization]; order and patterns suddenly emerge. As a pot of water comes to a boil on the stove, the molecules in the unorganized pool fall into a circular motion and divide into an orderly series of convection cells that cycle together in a synchronized manner. The circular movement of heated air rising from a hot desert and descending also generates order as it moves sand particles around, leaving hexagonal patterns like the cells of a beehive in the sand. The pervasive pattern and organization in nature we see around us — whether in a hurricane or the improbable stability of Earth's atmosphere — is the dynamic order of far-from-equilibrium [FFE] systems, order that depends on the constant flow of energy to maintain integrity and structure [the heart of NET; see below]. This flow of energy is the music that sets chaotic matter dancing, giving birth to life and the beauty of the world.

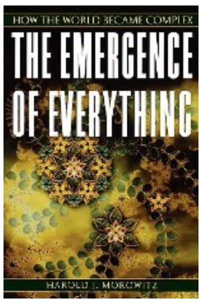
<Dumanoski continued> "These far-from-equilibrium [FFE] systems behave as coherent wholes that can only be understood in their entirety. For this reason, the analytic approach that seeks to understand the whole by only studying individual parts simply does not work, because this whole emerges from the relationship of these parts and thus transcends the mere sum of them. [This is emergence.] The shift away from atomism, mechanism and reductionism has been taking place on many fronts: in the study of far-from-equilibrium thermodynamics [NET] and self-organizing complexity by chemistry Nobel laureate Ilya Prigogine; in the 'ecology of mind' theory [a model of autopoiesis or 'self-making'] set forth by anthropologist and systems theorist Gregory Bateson; in the flowing process physics of David Bohm, which has much in common with ancient Greek philosopher Heraclitus's flux; in Nobel laureate Barbara McClintock's intuitive, empathetic, anti-reductionist 'feeling for the organism' and what might be called 'participatory science'; and in the far-from-equilibrium [FFE] metabolism of Earth described by James Lovelock [and Lynn Margulis]. Starting from very different perspectives, these various paths of exploration converge on a complex, dynamic, holistic picture of the world." — [**Alder's note:** I believe this is the best book written to date by any author or scientist about our planetary climate crisis and how to effectively address it. It explains climate change using complexity and explains why addressing this crisis must include replacing the mechanistic worldview of western culture — that emerged during three centuries of dominance by the mechanistic sciences — with new cultural maps based in complexity sciences and geophysiology.]

Ricard Solé and Brian Goodwin, *Signs of Life: How Complexity Pervades Biology*, 2000 —



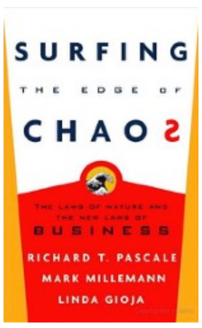
"A remarkable burst of creativity in science is transforming traditional disciplines at an extraordinary rate, catalyzing movements whereby old boundaries are dissolving and newly integrated territories are being defined. The new vision comes from the world of complexity, chaos and emergent order. This started in physics and mathematics but is now moving rapidly into the life sciences, where it is revealing new signatures of the creative processes that underlie the evolution of organisms. A distinctive sign of life is the emergence of new order out of the complexities of its material foundations. The concept of emergence, once regarded by many biologists as a vague and mystical concept with dangerous vitalist connotations** is now the central focus of the sciences of complexity. Here the question is, how can systems made up of components whose properties we understand well give rise to phenomena that are quite unexpected? Life is the most dramatic manifestation of this process, the domain of emergence par excellence. But the new sciences unite biology with physics in a manner that allows us to see the creative fabric of natural processes as a single dynamic unfolding. …. This is a new biological frontier that will leave its mark on the life sciences and then transform into something else. But it is likely to have longer-term consequences on our view of science itself. It will become evident that the new understanding of complex processes takes us beyond the traditional scientific perspective of prediction and control of nature, to a relationship of participation in natural processes that are unpredictable, though still intelligible." — [**Alder's note:** This is another of my favorite and strongly recommended books about biology and ecology that I use as a text for an advanced course. It is written for educated lay readers, yet enlightening to those with a PhD in biology. More challenging mathematical components and models are included in "side boxes" for those who wish to study them, but can be skipped without significant loss for more casual readers. These skillful authors begin with a chapter summarizing 85% of the principles introduced in Complexity 101, then apply them to biological systems in 9 chapters, including metabolism, genetics, embryology, physiology, brains, social insects, ecosystems and evolution. They finish with a chapter on city design and stock markets. **Vitalism is a movement that has unsuccessfully attempted to rise several times within biology over several centuries. It contends that the four known forces — gravity, electromagnetism, strong and weak forces — are insufficient to explain life and there must be a fifth or "vital" force. The hypothesis has been repeatedly rejected; there is no credible evidence for such a force. One value of complexity is that it helps explain life without vitalism.]

Harold Morowitz, *The Emergence of Everything: How the World Became Complex* —



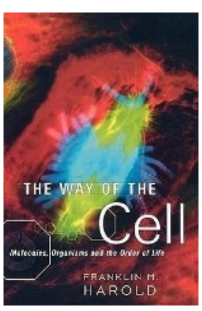
"At the end of the second millennium of the Common era, which has concluded the most dynamic and creative century in the entire history of science, we now see the world through the fresh perspective and understanding of the computer revolution and the study of complex systems. I entered college in the 1940s, and have seen the vast changes unfold before my eyes. I'm not sure that all contemporary scientists and policy-makers understand just how profound the changes in perspective have been during the past century. I believe that this conceptual revolution is comparable to the discovery of language and the discovery of mathematics. In the last few years, this new mode of thinking has begun to develop an exciting explanatory concept designated emergence, which develops previously unrealized ways of keeping our understanding of the past eons and illustrates how the universe, after a long and complex 12 billion year trajectory, has given us the human mind and modern man." — [**Alder's note:** I have issues with some of Morowitz's philosophical and spiritual extensions of the concept of emergence. But his understanding and explanation of its importance in science is, I believe, spot on.]

Richard Pascale, Mark Millemann, Linda Gioja, *Surfing the Edge of Chaos: The Laws of Nature and the New Laws of Business* —



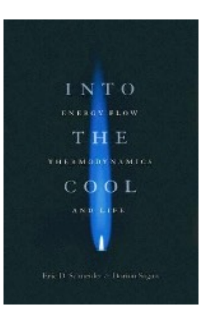
"There is a new scientific renaissance in the making. It will usher in new industries, alter how businesses compete, and change how companies are managed. This book explores the managerial implications of the new renaissance. .… [After a description of past scientific revolutions,] We are now entering another scientific renaissance. The magnets for inquiry are called complex adaptive systems. Also known as 'complexity science', this work grapples with the mysteries of life itself, and is propelled by the confluence of three streams of inquiry: (1) breakthrough discoveries in the life sciences (e.g., biology, medicine and ecology); (2) insights of the social sciences (e.g., sociology, psychology and economics); and (3) new developments in the hard sciences (e.g., physics, mathematics and information technology). The resulting work has revealed exciting insights into life and has opened up new avenues for management." — [**Alder's note:** Their treatment of the application of the principles to the corporations and institutions for which they consulted using case studies are well done and comprehensible even for those with little business knowledge. But they fall short on explaining the principles themselves. They are inaccurate in some places, conflate ideas in others. And the book is totally devoid of graphics and images; it is extremely difficult to explain principles of complexity using words alone. However, anyone with a Complexity 101-level understanding of complexity will understand it. I intend to use the ideas and case studies in this book and my knowledge of complexity to organize and operate a new business built around my work in Nova Scotia. Members of the business will study both the book and Complexity 101.]

Franklin Harold, *The Way of the Cell: Molecules, Organisms and the Order of Life* —



"In an interesting and altogether constructive sense, [Robert] Rosen [in his book *Life Itself: A Comprehensive Inquiry into the Nature, Origin and Fabrication of Life*, 1991] can perhaps be described as a latter-day vitalist. His quest for the principles that make organic systems different from inorganic ones does not lead him to invoke forces that breathe life into the common clay, but he does bid us to rethink the relationship between biology and physics, and that is quite radical itself. Both disciplines deal with systems, and for the past two centuries biologists have sought to interpret their subject by the extension of laws inferred by physicists from the study of simple mechanisms. This, in Rosen's view, puts the cart before the horse: in reality, simple systems such as gases or planetary orbits are special and limited instances, while complex systems represent the general case. If organisms are ever to be understood as material physical entities, physics will first have to be transformed into a science of complex systems. This metamorphosis is already underway, but has proven neither quick nor painless: after half a century, the thermodynamics of irreversible processes (those that predominate in the real world) have chalked up few concrete achievements and remains largely outside the main stream of both physics and biology. [That was true in 2001 when the book was published. But see *Into the Cool: Energy Flow Thermodynamics and Life* for a different view.] I am not at all certain where this line of inquiry can lead; but Rosen's viewpoint will intrigue anyone who suspects, as I do, that the elusive relationship between physics and biology holds the key to Schrödinger's riddle ['What is life?']." — [**Alder's note:** In my opinion, this is ***the*** best book on biology ever written for both scientists and the educated lay reader interested in biology and life. It devotes an entire chapter — #10 entitled "So, What is Life?" — to the principles of complexity and their effect on our understanding of life.]

Eric Schneider and Dorion Sagan, *Into the Cool: Energy Flow Thermodynamics and Life*, 2005 —



"Life, by any of the many definitions of complexity, is a complex system. Over the past thirty years a new science of 'complexity' has emerged and has been the focal point of many brilliant scientists around the world. Generally this view of the world is non-reductionist and offers many new possibilities to aid us in our understanding of life. This view of the world is a systems approach to the study of nature. By this we mean the search for universal laws, models or principles that hold for a broader class of systems irrespective of their particular kind. Ludwig von Bertalanffy, considered to be the father of systems theory, initiated research programs, searching for general principles that would apply to 'systems in general'. This new science sees emergent properties and is trying to integrate holistic and reductionist observations within the framework of complex systems." — [**Alder's note:** Even though one of the authors — Sagan, a writer and philosopher, not a scientist — holds an erroneous understanding of several other aspects of the complexity sciences, I still consider this to be the best book written to date for educated lay readers and scientists about a major component of complexity sciences: self-organization and non-equilibrium thermodynamics (NET), the latter of which is a ***major*** overhaul of thermodynamics applied to complex systems — including living ones. It redefines the second law of thermodynamics — widely considered to be the most important law in science — in terms of energy gradients instead of entropy, which turned out to be problematic both conceptually and practically: it cannot be measured in FFE systems. NET helps us understand that rather than contradict the 2nd law as creationists contend, the existence of life is dictated by the 2nd law and powered by dissipation of energy gradients. This should be common knowledge for all biologists.]