is life a
self-organized
critical
phenomenon?

The step from describing inert matter to describing biological life seems enormous, but maybe it isn’t. Perhaps the same principles that govern the organization of complexity in geophysics also govern the evolution of life on earth. Then nature would not suddenly have to invent a new organizational principle to allow live matter to emerge. It might well be that an observer who was around when life originated would see nothing noteworthy—only a continuous transition (which could be an “avalanche”) from simple chemical reactions to more and more complicated interactions with no sharp transition point indicating the exact moment when life began. Life cannot have started with a chemical substance as complicated as DNA, composed of four different, complicated molecules called nucleotides, connected into a string, and wound up in a double helix. DNA must itself represent a very advanced state of evolution, formed by massively contingent events, in a process usually referred to as prebiotic evolution. Perhaps the processes in that early period were based on the same principles as biology is

P. Bak, How Nature Works
today, so the splitting into biotic and prebiotic stages represents just another arbitrary division in a hierarchical chain of processes.

Maybe a thread can be woven all the way from astrophysics and geophysics to biology through a continuous, self-organized critical process. At this time all the intermediate stages of evolution progressing from chemistry to life are distant history, so we see geophysics and biology as two separate sciences.

Biology involves interactions among millions of species, each with numerous individuals. One can speculate that the dynamics could be similar to that of sandpiles with millions of interacting grains of sand. However, the realization of this idea in terms of a proper mathematical description is a long and tedious process. Much of my thinking along these lines took place at the Santa Fe Institute, mostly through interactions with Stuart Kauffman, who resides there. For three years Stuart and I were walking around in circles without being able to make a suitable model of evolution, but eventually this work paid off in a rather surprising turn of events.

The Santa Fe Institute

The Santa Fe Institute in New Mexico is a lively center for exchange and debate on complex systems. In the words of the economist Brian Arthur of Stanford University, now the Citibank Professor at the institute, “It is the only place where a biologist can come and hear an economist explain how a jet engine works.” The institute brings together many of the most imaginative thinkers from vastly different fields in an open environment. The meetings at Santa Fe are continuous brain storms.

The institute is the brainchild of George A. Cowan, former head of research at Los Alamos National Laboratory near Santa Fe. It soon received the backing of top scientists in a number of fields, including Philip W. Anderson, Nobel Prize winner for his work on condensed matter physics, Murray Gell-Man, Nobel Prize winner for the discovery of quarks, which are among the most fundamental of all particles, and Kenneth Arrow, economist and Nobel Prize winner for the general equilibrium theory of economics.

The reductionist approach has always been the royal road to the Nobel Prize. Ironically, the philosophy of the institute is quite orthogonal to the re-