In Memoriam Peter S. Albin 1934--2008

by Duncan K. Foley

Our main purpose today is to remember Pete Albin's remarkable work as a scientist and educator. His life had many other remarkable aspects, including the ordeal that his stroke and its aftermath imposed on him and his family. I would like to say just a few words about that experience before moving on to Pete's work.

I imagine that people must sometimes experience more difficult medical and human situations than Pete's, and perhaps some people here today have, but what Pete and his family went through was well beyond the limits of my personal experience, and in a realm most of us thankfully encounter only in empathy and imagination. Pete's condition required constant attention and care, and left him much of the time in pain and all of the time in a state of helpless need. The result for his family and caretakers was an unending series of days full of hard, unpleasant work, difficult personal interactions, and dealing with chronic suffering, for which the prospect of success was at best that the next day would be a little harder. I remain in awe of the patience and competence of Pete's caretakers, among them Dorota, Marta, and Diana, of the human strength and resilience of his children, Elizabeth and John, and of his wife, Pat, who in the midst of her own medical problems had to confront the nightmarish tangle our society has created around medical treatment and disability, and Pete's own stoicism. I should not, perhaps, paint too dark a picture, since there were some bright spots, including Pete's great pleasure in his children and grandchild, and his gleeful competitive pleasure in regularly crushing me in Scrabble games over these years.

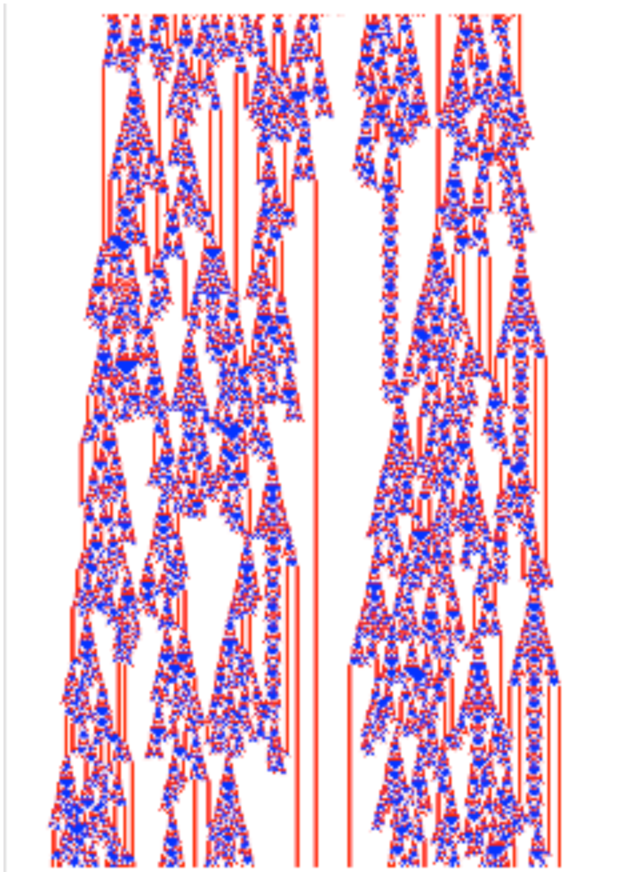
I met Pete Albin in around 1988 at a workshop at the New School (before I taught there) organized by Willi Semmler around the theme of complex dynamics in economic models. I had already met Pete's son John, who took my course in Marxist economics at Barnard in the early 1980s. Pete presented a paper using the framework of a cellular automaton to model macroeconomic fluctuations. I was intrigued with the novelty of the statistical predictions of this type of model, fascinated by the beauty of the graphic representations (as Pete himself was), and dissatisfied with what looked to me to be an overly superficial articulation of the economic foundations and formal superstructure of the model. I talked to Pete about these reactions, which led to a longer series of conversations, joint work developing of another model using cellular automaton methods to address one of the most fundamental problems in economic theory, the dynamics of market exchange, and a collaboration that changed my professional and intellectual life.

I later learned that Pete, after working in an unconventional mode on a variety of more conventional political economic problems, including poverty, the operation of financial markets, and the organization of productive tasks, had encountered the world of complexity science through Steven Wolfram's papers on cellular automata in the early 1980s. The cellular automaton is a particularly simple nonlinear dynamical system made up of a collection of "cells", usually arranged on a line, in a circle, or on a plane or a doughnut-shaped torus, each of which can at any moment be in one of a set of "states". The cellular automaton evolves in discrete steps, like the ticking of a clock. At each tick each cell moves to a new state determined by the states of its neighbors through a "rule" that characterizes the particular automaton. Very simple rules can lead to very complex aggregate behavior of a system of such cells. Physicists, mathematicians, and computer scientists like John von Neumann, John Conway, Marvin Minsky, Arthur Burks, and Wolfram had seen in the complexity of cellular automata a tractable pathway to understanding a wide variety of natural phenomena, including complex solid-state material systems, biological systems like the cell and the brain, the stripes of the zebra and the branching patterns of plants. Pete was one of the first few individuals to see the potential of this approach to complexity for understanding social and particularly economic complexity.

Pete's extraordinary insight was to map complex social interactions onto the abstract structure of the cellular automaton. For example, in the paper on macroeconomic fluctuations he gave at the workshop where I met him, he regards the cells as representing firms in a large economy, the states as their investment plans, and the rule as a system of connections among neighboring firms. Running this cellular automaton produces a complex history of firm interactions, as well as an aggregate time series of total economic activity, thus creating a "microfounded" macroeconomic model.

Pete saw well beyond this fundamental point, which began to dawn on the economics profession as a whole only a decade or more after his pioneering efforts. He saw that certain deep properties of cellular automata had fundamental implications for social dynamics, epistemology, and theory. These implications are still in the process of percolating through the fields of economics and social theory, and I believe will in time transform the way economists conceptualize social interaction and coordination.

Wolfram proposed four types to describe cellular automaton rules. Cellular automata of type 1 settle down to a single uniform state, like a mechanical system that finds a unique equilibrium; those of type 2 settle down to regular oscillations of state in time and space, like a mechanical system that undergoes limit-cycle oscillations; and those of type 3 explode into chaotic a-periodic patterns like an entropic thermodynamic system which are unpredictable in detail, but statistically regular. Pete was particularly fascinated by Wolfram's type 4, which are rules that evolve complex, non-monotonic structures exhibiting intractable statistical irregularities. He saw in these type 4 cellular automata a highly abstract model of social and economic interactions. Type 4 cellular automata are in fact capable of universal computation like a general-purpose Turing machine. Pete used the type 4 cellular automaton to make a fundamental critique of conventional economic theory.



A type 4 1-dimensional 3-state cellular automaton. Time evolves downward; the states are white, red, and blue reading across any row, which represents one time period.

The first pillar of conventional economics to succumb to this critique is the assumption that individual agents in complex economic systems have "rational expectations" or "perfect foresight" in equilibrium. If the economy or its subsystems exhibit type 4 behavior, it is theoretically impossible for an agent, even endowed with the computational power of a universal Turing machine, to predict the evolution of the system (or even, practically speaking, to maintain an accurate picture of its current state). Thus Pete argued that it is necessary to regard economic agents as having bounded computational and information processing capacity, and thus to have bounded rationality. For Pete this was a happy convergence of his own thinking with the work of Herbert Simon, whose paradigm-breaking thinking about human problem-solving and organization Pete greatly admired. Simon's generous review of the book of Pete's essays I edited for Princeton University Press was a high moment of scientific validation for Pete's work.

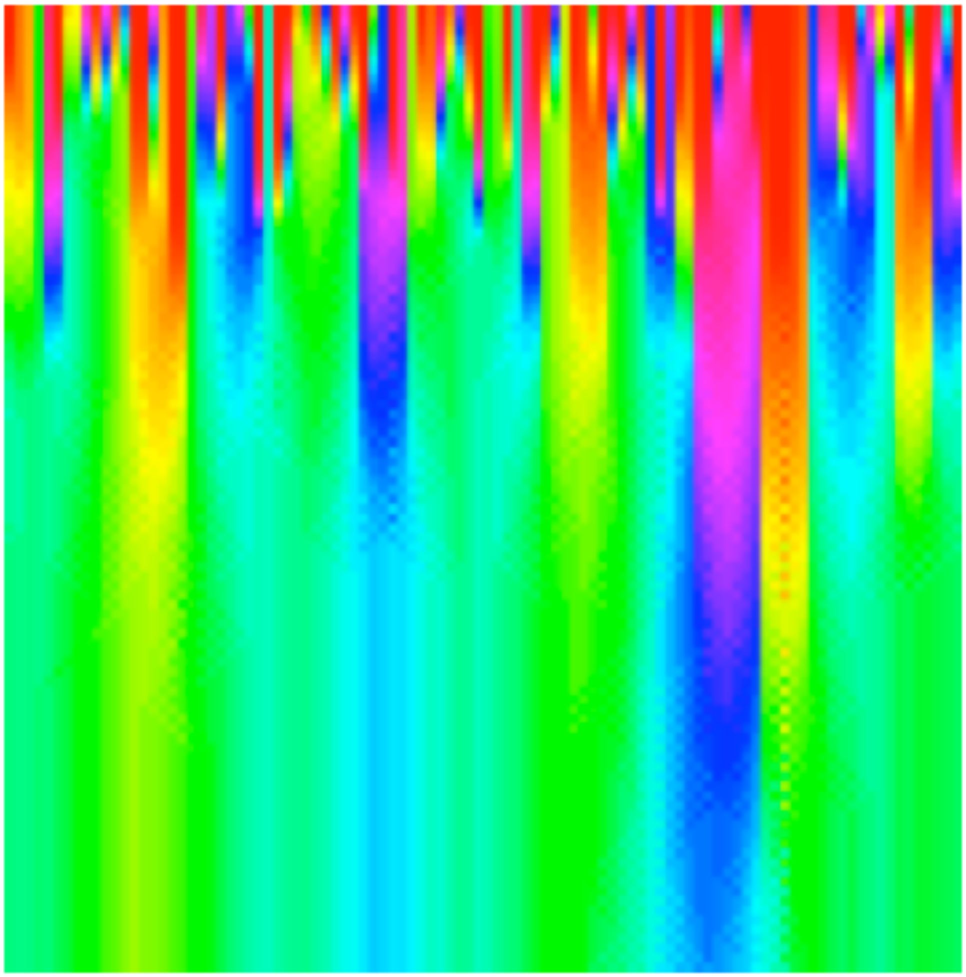
The behavior of type 4 cellular automata undermines important epistemological presumptions of conventional economics as well. The evolution of systems, such as the capitalist economy, which have type 4 complexity, cannot in principle be predicted except by actually simulating the system itself or a system of equal complexity. Furthermore, because type 4 systems do not as a whole exhibit the statistical regularities of type 3 systems, it is not possible to make valid statistical projections for such systems.

The economist can understand the qualitative behavior of type 4 systems, but cannot hope to make detailed predictions or even statistical generalizations about all aspects of complex economic systems. It may be possible to learn a lot about the local rules that govern the evolution of the economy, but if these rules lead to type 4 complexity, the actual evolution of the economy will be open and unpredictable. Complexity thus poses "bounds and barriers" not just to the cognitive achievements we can expect individual economic agents to exhibit, but to the epistemological aspirations of economic analysis itself.

These are profound, disturbing, and revolutionary observations. Pete was in the forefront of the small group of economists and physicists contemplating economic systems who reached these conclusions in the late 1980s. The problem of understanding the full implications of these ideas continues to attract the intellectual energy of scholars like Brian Arthur at the Santa Fe Institute, as well as a group of younger scholars including Rob Axtell, Blake LeBaron, Leanne Ussher, and Leigh Tesfatsion, who find themselves following in Pete's footsteps.

While the critical force of Pete's thinking about complexity is bound to have far-reaching ramifications, Pete did not neglect the constructive tasks of model-building as a research program. He was also a pioneer in using complex systems, again cellular automata or modifications of them, as models of real-world economic phenomena and guides to economic policy. He elaborated the model of economic fluctuations based on local firm interactions I mentioned before as a tool for thinking about monetary policy, through the ingenious device of introducing another agent, the central bank, into the model as a neighbor of every firm. He was able in this setting to show that a change in central bank policy (modeled as a cellular automaton rule) could not only change the detailed path of the stylized macro-economy, but, critically, its complexity type. Policy can transform an economy from type 2 or 3 to type 4 complexity behavior. This observation opens up a whole new set of questions about the effects of policy in a complex economy. Pete's model also introduces an important methodological innovation in the cellular automaton literature, a weak global interaction (through the central bank) which supplements and alters the local interactions characteristic of classic cellular automata.

The paper Pete and I worked on in the late 1980s adapted the cellular automaton setting to the classic economic problem of exchange. In our model agents holding endowments of two goods are located around a circle, and interact with their close neighbors to exchange the two goods in a completely decentralized fashion. This setup is in fact a cellular automaton, in which an agent's state is its current holding of goods, which changes according to the exchange rule depending on the states of the neighboring agents. This research had consequences perhaps not expected or intended by Pete or myself. We found that decentralized exchange can achieve a good approximation of an efficient allocation of resources, but introduces systematic inequality in the final allocation because agents exchange at disequilibrium prices on the path. This simulation finding linked up with earlier work on disequilibrium trading of Uzawa, Hahn and Negishi, and Smale, and emphasized the inadequacy of the conventional treatment of efficiency and distribution in economic theory. With the publication of this paper I found myself in the unexpected, but not unwelcome, position of being regarded as part of the community of complexity science. The insights from this work have had a powerful influence on my work on statistical equilibrium models of markets, and on the more general issue of the relation between physical thermodynamics and economic models of equilibrium.



In the Albin-Foley exchange model the agents are arrayed in a circle (represented by a line here). The agents' willingness-to-pay is color-coded. Time progresses downward. The convergence of the colors over time shows the equalization of willingness-to-pay as a result of decentralized exchange.

I'd like to close these remarks with Pete's favorite cellular automaton, the "Game of Life", a two-dimensional cellular automaton invented by John Conway which many people have on their personal computers. The cells in Life are either "on" (alive) or "off" (dead), which are the two states. The rules governing the evolution of the system are based on counting the number of neighbors of a cell which are on: 1. Death: if the count is less than 2 or greater than 3, the current cell is switched off. 2. Survival: if (a) the count is exactly 2, or (b) the count is exactly 3 and the current cell is on, the current cell is left unchanged. 3. Birth: if the current cell is off and the count is exactly 3, the current cell is switched on. Life is a type 4 cellular automaton; it is possible to set up initial patterns that act as a universal computer or Turing machine. Pete was particularly interested in the difficulty of predicting the local evolution of behavior in a neighborhood because of the long-term interactions possible in this system. He speculated that Life-like strategies might support cooperation in multi-person versions of the Prisoners' Dilemma game such as shared-resource games, while less complex systems would find themselves vulnerable to exploitation by opportunistic free-riding agents by being too predictable. Pete spent many hours looking at the endlessly ramifying patterns produced by Life, which, like Pete himself, show a restless tendency to innovate and explore new possibilities.

The papers I discuss here are reprinted in Peter S. Albin, "Barriers and Bounds to Rationality: Essays on Economic Complexity and Dynamics in Interactive Systems" edited and with an Introduction by Duncan K. Foley, Princeton University Press, 1998.