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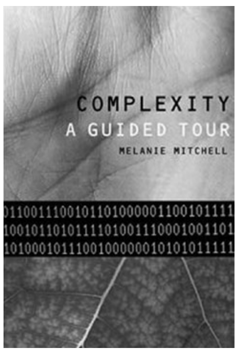
BOOK REVIEW

Complexity: *A Guided Tour by Melanie Mitchell, Ph.D.*

Reviewed by Dave Snell



One of my favorite books from the early 1980s was a huge tome titled *Gödel, Escher, Bach: An Eternal Golden Braid,* by Douglas Hofstadter, a pioneer in Artificial Intelligence (AI). Hofstadter described GEB (the initials became a popular abbreviation for his book) as "a metaphorical fugue on minds and machines in the spirit of Lewis Carroll." At the time I was just getting interested in AI and I found GEB fascinating. Apparently, I was not alone. Melanie Mitchell, then a high school mathematics teacher in New York, found it "one of those life-changing events that one can never anticipate."

She wrote to Hofstadter indicating she wanted to study under him as a graduate student. Receiving no reply, she later approached him in person when he gave a lecture at MIT. He handed her off to a graduate student. She was "disappointed, but not deterred" and after several more follow-up calls to him, she managed, through her persistence, to convince him of her passion for AI—a topic that eventually was absorbed into complexity science. Eventually, she moved to Michigan and earned her Ph.D. under Hofstadter and John Holland, another complexity science pioneer. I mention this history to try to convey the contagious enthusiasm for complexity science that Dr. Mitchell exudes in her book. She seems to prefer the term complexity sciences, since this is such a cross disciplinary subject; but in this review I'll use the more common term, complexity science.

Mitchell starts with an acknowledgement to the Santa Fe Institute (SFI) where she directed an SFI Complex Systems Summer School. The SFI seems to be the current epicenter for complexity science research, and this book is an expansion of the author's series of SFI lectures on "The Past and Future of the Sciences of Complexity," with updated material reflecting new perspectives from 2008 and 2009.

Previous knowledge of complexity science is unnecessary, as the first chapter starts out with a series of examples to describe what is meant by complexity. This was useful since the topic seems to evoke many different definitions from scientists and practitioners. An actuary often likes to start with some definition of the topic under study; but a rigorous and widely accepted definition of complexity science just does not exist yet. On the other hand, we are eagerly embracing the study of enterprise risk management (ERM) to the point of promoting the Chartered Enterprise Risk Analyst (CERA) designation as an international credential of expertise in risk management—even though we may differ considerably in our opinions about what constitutes risk. In a similar vein, Mitchell's examples make it clear what falls into the realm of complexity. The examples run the gamut from insect colonies to the human brain; and from immune systems to economies and the World Wide Web. In some respects, ERM seems like an application of complexity science; and quoting A.S. Eddington, the astronomer who first demonstrated that Einstein's Theory of Relativity worked in the real world, "We need scarcely add that the contemplation in natural science of a wider domain than the actual leads to a far better understanding of the actual." I submit that a study of the wider domain of complexity science can help us better understand risk management. In fact, lest the actuary reading this assume that the book mentions only theory and some science applications, the author peppers her theory with references to practical financial applications in several sections. She explains early on that:

> Economies are complex systems in which the "simple, microscopic" components consist of people (or companies) buying and selling goods, and the collective behavior is the complex, hard-to-predict behavior of markets as a whole, such as changes in the price of housing in different areas of the country or fluctuations in stock prices.

and later in the book she gives specific examples:

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> GAs [Genetic Algorithms] have been used by several financial organizations for various tasks: detecting fraudulent trades (London Stock Exchange), analysis of credit card data (Capital One), and forecasting financial markets and portfolio optimization (First Quadrant).

Her extensive notes section refers the reader to details about each of these specific applications.

In *Complexity: A Guided Tour*, we are given a short history lesson on the roots of dynamical systems theory, chaos and prediction. Again, the examples help guide the reader through an inductive learning process. Deterministic chaos, for example, is introduced via the famous logistic map that results from varying values of R in the seemingly simple equation $x_{t+1}=R\cdot x_t\cdot(1-x_t)$ where $0\leq x_t\leq 1$. Along the way, we hone in on Feigenbaum's constant, a universal constant for functions approaching chaos via period doubling, and the fact that it applies outside the realm of pure mathematics and shows up in electronic circuits, lasers and chemical reactions.

Now, we are ready to approach the concepts of information, energy, work and entropy. This is explained through stories about the development of the Second Law of Thermodynamics, Maxwell's Demon and Shannon's Information Theory. Moving along to computation, Mitchell guides us through topics such as "What is Computation and What Can Be Computed?" She describes Hilbert's Problems and Godel's Theorem, which proved that not all mathematical questions are computable. Then she covers Turing machines, where the goal is to mimic human behavior so well as to fool a human, and this leads into a chapter on evolution. Her primer on evolution summarizes pre-Darwin, Darwin, Mendel and the Modern Synthesis, and leads quite naturally into the next chapter, on Genetics. Skipping quickly through an admittedly simplified treatment of DNA and RNA, Mitchell leads us into the geometry of fractals, and the underlying power laws that describe them when normal measurement techniques fail us.

Now with approximately 100 pages of history and basic tutorials behind us, we can begin the next parts of the book, which deal with topics such as life and evolution in computers, cellular automata, information processing in living systems, genetic algorithms, ant colony optimizations, and the mystery of scaling. Clearly oriented towards AI, the author devotes a major chapter to applying network science to real-world networks—such as the brain.

Each topic is approached in a logical, understandable manner. In addition though, as a reader I felt the excitement of the discovery process as I read about Von Neumann's self-reproducing automation, the "New Kind of Science" from Wolfram, and the gradual increase in intelligence of Robby, the soda-can-collecting robot, like the movie robot *WALL·E,* which eventually outperformed the author in developing its own clean-up strategy.

A chapter is devoted to an overview of the author's development of "copycat"—a program she wrote for her doctoral dissertation that makes analogies in the letter-string world by using reasoning believed similar to that used by humans as we make analogies to understand our world.

The examples often caused me to stop and write a quick spreadsheet or program to further explore the particular subject.

This is one of the first books I read on complexity science; and admittedly many of the ones I read afterwards were more narrowly focused; and some went into more detail, or provided even more memorable examples on particular complexity science topics. However, this book gave me a base level understanding of a lot of topics that previously were just fancy sounding phrases. More than that, it nurtured my initial interest in complexity science and left me with a voracious appetite for more! The subtitle is appropriate. This is truly a *guided* tour for complexity. Dr. Mitchell is an excellent guide; and I recommend her for your visit to the amazing world of complexity science. ▼

Dave Snell

Dave Snell, ASA, MAAA, is technology evangelist with RGA Reinsurance Company in Chesterfield, Mo. He can be reached at *dsnell@rgare.com*.