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Masterminds of Artificial Intelligence

Marvin Minsky and Seymour Papert

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The world lost two great scientists this year. Marvin Minsky passed away on 24 January 2016, and Seymour Papert passed away on 31 July. They were both 88 years old. Their careers at MIT were closely joined, both in artificial intelligence (AI) and in other fields. This article will highlight some of their contributions and one "controversy" that they jointly sparked. There are a number of YouTube videos of talks and lectures given by both of these masterminds that are well worth watching (see, for example, https://youtu.be/-pb3z2w9gDg). Moreover, a friend's chapter-length biography of Minsky recently appeared in Stephen Wolfram's *Idea Makers*.[1]

Early Life and Education

Minsky was born in 1927 in New York City to prosperous parents. He received a good education from the beginning, including at the Bronx High School of Science and the Phillips Academy. By the last years of World War II, he was old enough to be drafted and spent 1944–1945 in the US Navy. At the end of hostilities, he returned to his schooling, obtaining a bachelor's degree from Harvard in 1950 and a PhD from Princeton in 1954, both in mathematics. His thesis was titled "Theory of Neural-Analog Reinforcement Systems and Its Application to the Brain Model Problem." This was an early contribution to the field of *artificial neural networks* (ANNs) which is the same field in which he and Papert created the aforementioned controversy, which we discuss later. He joined the MIT faculty in 1958 (see http://web.media.mit.edu/~minsky/minskybiog.html).

Papert was born in 1927 in South Africa and was educated there at the University of the Witwatersrand, receiving a BA in philosophy in 1949 and a PhD in mathematics in 1952 (see https://en.m.wikipedia.org/wiki/Seymour_Papert). He then moved to England, where he worked at St. John's College, Cambridge, and earned a second PhD in mathematics in 1959. Papert was a prominent activist against South African apartheid policies during his university education. He also worked at the Henri Poincaré Institute at the University of Paris, the University of Geneva (where he worked with Jean Piaget; see https://en.m.wikipedia.org/wiki/Jean_Piaget), and the National Physical Laboratory in London before becoming a research associate at MIT in 1963.

Careers at MIT

Minsky is best known as a father of AI, having cofounded the MIT AI laboratory in 1959 (with John McCarthy, who subsequently moved to Stanford). However, he made contributions in many domains, including graphics,

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symbolic mathematical computation, knowledge representation, commonsensical semantics, machine perception, and both symbolic and connectionist learning. He was also a pioneer of robotics and telepresence. He designed and built some of the first visual scanners—mechanical hands with tactile sensors. He also built one of the first "turtles" for Papert's LOGO programming language, including the software and hardware interfaces. He published a major work summarizing many years of thought in 1985, titled *The Society of Mind* (https://en.m.wikipedia.org/wiki/Society_of_Mind).[2]

Papert is perhaps best known for his contributions to education, and he also made contributions in other fields. Minsky appointed him codirector of the MIT AI laboratory in 1967. Based on Piaget's constructivist learning theory, for which he was a principle advocate, Papert codesigned the LOGO programming language, which influenced later languages such as Smalltalk and Scratch (see https://en.m.wikipedia.org/wiki/Logo_(programming_language)). In 1980, he published *Mindstorms: Children, Computers, and Powerful Ideas* (https://en.m.wikipedia.org/wiki/Mindstorms_(book)).[3]

Minsky's Society of Mind

The Society of Mind is more speculative cognitive science and philosophy than AI. That is, it proposes that the human mind is a "society" of independent agents that evolution produced over time to deal with various problems that humans needed to solve. The book consists of 270 one-page chapters, each dealing with a brain agent, process, or interconnection issue.

In 2006, Minsky published a sequel, *The Emotion Machine*,[4] which proposes theories that could account for human higher-level feelings, goals, emotions, and conscious thoughts in terms of multiple levels of processes, some of which can reflect on the others. This view of consciousness is process-oriented, in that consciousness is seen to be the result of more than 20 processes going on in the human brain.

If *The Society of Mind* and *The Emotion Machine* contain ideas that can be implemented in computers, then Minsky has indeed provided a path for AI researchers to follow. If cognitive neuroscience discovers that the agents and processes he identifies are indeed present in the structures of the brain, then he has identified major components of "natural intelligence." Perhaps the time is not too far off when these conjectures will be supported or refuted.

Papert's LOGO

As mentioned, Papert had worked with Piaget in Geneva and was an advocate for his constructivist learning theory (https://en.m.wikipedia.org/wiki/Constructivism_(philosophy_of_education)). Papert's ideas were given the confusingly similar name of constructionist learning theory. In a US National Science Foundation proposal, he defined this theory as follows (see https://en.m.wikipedia.org/wiki/Constructionism_(learning_theory)):

> *Constructionism is a mnemonic for two aspects of the theory of science education underlying this project. From constructivist theories of psychology, we take a view of learning as a reconstruction rather than as a transmission of knowledge. Then we extend the idea of manipulative materials to the idea that learning is most effective when part of an activity the learner experiences as constructing a meaningful product.*

The idea of the (child) learner constructing a meaningful product was realized by constructing LOGO programs and robotic devices that could be controlled by LOGO programs. Papert's coinventor of LOGO, Wally Feurzeig (https://en.m.wikipedia.org/wiki/Wally_Feurzeig), had been developing conversational programming languages at BBN based on Fortran, which was designed for mathematical problems. By focusing on nonmathematical problems, they defined a language simple enough for children to learn. And by connecting the language to the control of "turtles" and other robotic devices, they provided additional motivation (fun) for young learners.

Papert expressed these ideas in *Mindstorms: Children, Computers, and Powerful Ideas*.[3] He also collaborated with the construction toy manufacturer Lego on their LOGO-programmable Lego Mindstorms robotics kits, which were named after his book. The third generation of Lego Mindstorms was released in 2013 (see https://en.m.wikipedia.org/wiki/Lego_Mindstorms_EV3). A Lego Mindstorms kit contains software and hardware to create customizable, programmable robots. It includes an intelligent brick computer that controls the system, a set of modular sensors and motors, and Lego parts from the Technic line to create the mechanical systems. (Several different programming languages can now be used in Lego Mindstorms.)

Artificial Neural Net Controversy and Deep Learning

The subject of ANNs goes back to 1943, when Warren McCulloch and Walter Pitts created a computational model for neural networks (https://en.m.wikipedia.org/wiki/Artificial_neural_network). As mentioned, Minsky's PhD dissertation had contributed to the early study of ANNs. But in

1969, Minsky and Papert coauthored a book titled *Perceptrons*,[5] which gave rise to a controversy (over what they really said) that is still being argued today. In their book, they showed that "simple ANNs" were quite limited in computational power. The assumption that "complex ANNs" (technically called hidden-layer ANNs) were also of limited power might have been made by Minsky and Papert, but not in this book. One commentator stated that "the often-miscited Minsky/Papert text caused a significant decline in interest and funding of neural network research," and that it would take 10 years for neural network research to experience a resurgence in the 1980s. (An expanded edition of *Perceptrons*[6] was reprinted in 1987 with some errors from the original text shown and corrected; see https://en.m.wikipedia.org/wiki/Perceptron). Another commentator, a researcher at the MIT AI lab, quoted Minsky and Papert in the 1971 "Report of Project MAC,"—directed at funding agencies—on "gamba networks" (see https://en.m.wikipedia.org/wiki/Perceptrons_(book)):

> *Virtually nothing is known about the computational capabilities of [these machines]. We believe that [they] can do little more than can a low order perceptron.*

(See www.ucs.louisiana.edu/~isb9112/dept/phil341/histconn.html for a second view of this history.)

By the 2000s, hidden-layer ANNs had proven to be very powerful and in fact were powering many real AI applications. Hidden-layer ANNs are now part of the family of deep learning algorithms (https://en.m.wikipedia.org/wiki/Deep_learning), which has propelled us from an "AI winter" into an "AI summer."

The authority of Minsky and Papert was evident in that their negative view of ANNs was probably a factor in discouraging researchers and funders of research from further study of ANNs at that time. Their authority arose, of course, from their many important contributions to AI and allied fields. They will be remembered more for those contributions than for the controversy.

References

1. S. Wolfram, *Idea Makers: Personal Perspectives on the Lives & Ideas of Some Notable People*, Wolfram Media, 2016.
2. M. Minsky, *The Society of Mind*, Simon & Schuster, 1988.
3. S.A. Papert, *Mindstorms: Children, Computers, and Powerful Ideas*, Basic Books, 1980.
4. M. Minsky, *The Emotion Machine: Commonsense Thinking, Artificial Intelligence, and the Future of the Human Mind*, Simon & Schuster, 2006.
5. M. Minsky and S.A. Papert, *Perceptrons*, MIT Press, 1969.
6. M. Minsky and S.A. Papert, *Perceptrons: An Introduction to Computational Geometry*, expanded ed., MIT Press, 1987.

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