Norbert Wiener's earlier work may prove more important

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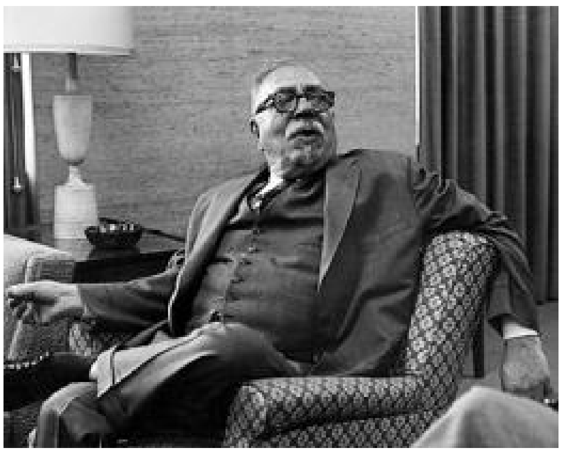

Norbert Wiener, the MIT mathematician best known as the father of cybernetics, whose work had important implications for control theory and signal processing, among other disciplines. Credit: The MIT Museum

Norbert Wiener, the mathematician and former child prodigy who won the National Medal of Science in 1963, figures prominently in MIT lore. After entering Tufts University at 11 and getting his PhD from Harvard at 18, he joined the MIT faculty at 23 and spent much of the next 40 years rambling the Institute's halls, depositing the ashes of his signature cigar in the chalk trays of his colleagues' blackboards, volubly holding forth on a bewildering range of topics, and, along the way, helping create the pop-culture archetype of the absent-minded professor.

In his lifetime, Wiener was best known for *Cybernetics*, a book he published in 1948, when he was in his mid-50s, which attempted to unify the study of biological and electromechanical systems through common principles of feedback, communication and control. The book's title — Wiener's own coinage, from the Greek for "steersman" — lives on in words like "cyborg" and "cyberspace," and researchers in a host of disciplines drew inspiration from Wiener's syncretic vision.

But in the United States and Western Europe, cybernetics as an autonomous discipline never really got off the ground. (Interestingly, departments of cybernetics did spring up in several Eastern-bloc states, and some of them still persist today.) Wiener's ideas ended up blending together with those of a number of his contemporaries to help create the intellectual backdrop against which engineering is done today. But it's difficult to isolate a single strain of thought in *Cybernetics* that had a lasting influence on subsequent scientific research.

Much of Wiener's earlier work, however, did have such an influence. In the early '20s, as a newly minted MIT professor, Wiener became interested in Brownian motion, the tendency of a small particle suspended on the surface of a fluid to meander about, buffeted by the vibration of the surrounding molecules. Brownian motion is the paradigm of a so-called stochastic process — one whose outcome is totally random. Wiener devised the first mathematical description of Brownian motion that allowed it to be quantified probabilistically. You can't mathematically predict where a particle wandering around a Petri dish will wind up, but you can calculate the probability that it will, say, end up in some region of the dish after a specified amount of time.

Wiener's probabilistic description applies to more than just specks of dust floating in Petri dishes. It's been used to characterize the random electromagnetic noise that corrupts radio signals, the quantum behavior of particles, and the fluctuations of the stock market. "It's a fundamental building block in stochastic models and stochastic control," says Sanjoy

Mitter, a professor of electrical engineering in MIT's Laboratory for Information and Decision Systems. Take, for instance, the famous Black-Scholes equation used to price stock options. "Without the Wiener measure, there's no Black-Scholes," says Mitter. "That might be a slight exaggeration, but not much."

Weighty problems

During World War II, Wiener received a government contract to help build a system that improved the accuracy of antiaircraft guns by predicting the future locations of aerial targets. Wiener envisioned a target's flight path as a series of discrete measurements. Since airplanes don't leap about the sky randomly, each new measurement is in some way correlated with the one that immediately preceded it, and, to a somewhat lesser degree, with the one preceding that, and so on, until you reach so far back in time that you come to measurements that have nothing to do with the target's current position. Previous measurements thus offer some clues to future measurements; the trick is determining how much weight to give each of the previous measurements in calculating the next one. "What you want to do is minimize, in Wiener's case, the mean square error in the prediction," says Alan Oppenheim, Ford Professor of Engineering and head of MIT's Digital Signal Processing Group. "That starts to get into mathematics, and then that starts to give you optimum weights. Getting those weights correct is what Wiener was doing."

The same type of correlation between discrete time measurements can also be used to filter noise out of a signal, and indeed, Wiener's wartime work (together with simultaneous but independent work by the Russian mathematician Andrey Kolmogorov) gave rise to the field of statistical filtering, which today plays a role in radio transmission, computer vision and vehicle navigation, among other applications.

The recognition that the same statistical techniques applied to problems of control — predicting how a system will respond to control signals — and communications — extracting a signal from the surrounding noise — was the foundational insight of cybernetics. "But to be honest, I don't think Wiener had really worked it out," says Mitter — who adds that much of his own research for the last 10 or 15 years has concentrated on making rigorous the connection that Wiener sketched.

"An important contribution of cybernetics was to introduce engineering principles to life-science people," says Robert Fano, a professor emeritus of electrical engineering and computer science, referring in particular to a series of seminars on cybernetics that Wiener hosted in the late 1940s, which were as well attended by life scientists as by electrical engineers.

Peripatetic professor

Fano credits his early interest in information theory, the discipline established by MIT alum (and future professor) Claude Shannon's 1948 paper "A Mathematical Theory of Communication," to Wiener, who during one of his characteristic perambulations around MIT appeared in the doorway of Fano's office and said, "You know, information is entropy." Trying to make sense of that cryptic comment (it turns out that standard measures of entropy from thermodynamics can be adapted to describe the probability of accurately reconstructing a corrupted communications signal) led Fano to develop, independently, the first theorem of Shannon's theory. Shannon asked him to publish the work quickly, so that he could cite it in his groundbreaking paper.

Fano also gives credence to some of the famous anecdotes about Wiener's absentmindedness: the time he reported the theft of his car to the police, only to discover that he had driven it to Providence for a talk and taken the train back to Boston; the conversation in an MIT hallway he concluded by asking his interlocutor which way he had been heading when he stopped to chat, greeting the answer by saying, "Good! That means I've already had lunch." Fano recalls driving to the MIT campus one rainy morning and spotting Wiener on the bridge between Boston and Cambridge, strolling along with his raincoat unbuttoned. Fano stopped to give him a ride, but, he says, once they pulled into the MIT parking lot, "I had a hell of a time getting him out of the car," so absorbed was Wiener in his disquisition on whatever topic had struck his fancy.

Wiener may have frequently seemed oblivious to the world around him, and he may have lived in an intellectual bubble from an early age. But David Mindell, the Dibner Professor of the History of Engineering and Manufacturing and director of MIT's Program in Science, Technology, and Society, whose book Between Human and Machine traces the intellectual history of cybernetics, points out that "for a mathematician — and he was quite an accomplished mathematician — he had an unusual interest in engineering and the engineering applications of what he was doing. And that to me is a very MIT thing."

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