Arthur Strong Wightman

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Arthur Strong Wightman

With the passing of Arthur Strong Wightman earlier this year, modern mathematical physics lost one of its founding fathers.

Born in Rochester, New York, on 30 March 1922, Wightman received his BA in physics from Yale University in 1942. After service in the US Navy, he earned his PhD in physics from Princeton University in 1949 under the direction of John Wheeler. Subsequently, Wightman spent almost all of his academic career at Princeton, eventually as Thomas D. Jones Professor of Mathematical Physics. He was a gentleman of truly encyclopedic culture, at ease in places as diverse as France, Japan, and Australia. His honors include the American Physical Society's 1969 Dannie Heineman Prize for Mathematical Physics, the American Mathematical Society's 1976 Josiah Willard Gibbs Lectureship, and the International Association of Mathematical Physics's 1997 Henri Poincaré Prize.

When Wightman started work in the early 1950s, physicists were trying hard to study quantum field theories but lacked any clear idea of what such a theory was. Wightman's principal achievement was that he provided a clear and unambiguous mathematical definition of a quantum field theory, which allowed him and others to prove general properties such as the connection between spin and statistics. In the 1960s Wightman and his students launched the constructive field theory program, aimed at studying specific examples of that structure. The work of Wightman and his school had an unparalleled influence over a whole generation of mathematical physicists.

Clarity was the guiding thread in Wightman's life. The Gårding–Wightman axioms, which combine the principles of quantum mechanics and special relativity, define a quantum field theory as a set of operator-valued fields in Hilbert space that satisfies certain natural properties. The Wightman reconstruction theorem then connects that structure to the properties of vacuum expectation values of field products—what everyone, except Wightman himself, soon came to call Wightman functions.

The connection between spin and statistics—the fact that particles with integer spin are bosons and particles with half-integer spin are fermions—was considered by Wolfgang Pauli as the main physical property of quantum systems that lacked a good explanation. Within the Gårding–Wightman framework, however, *PCT* (parity, charge conjugation, and time reversal) symmetry and the connection between spin and statistics simply became theorems, as expertly expounded in the classic treatise *PCT, Spin and Statistics, and All That* (W. A. Benjamin, 1964), written by Wightman and Raymond Streater.

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Arthur Strong Wightman

Wightman was the soul of the constructive field theory program, whose goal was to build explicit examples of interacting theories that fulfill its axioms. The Bargmann-Hall-Wightman theorem showed how the Wightman functions can be analytically continued to noncoinciding Euclidean points; conversely, the Osterwalder–Schrader axioms and reconstruction theorem allow one to build the Wightman functions from their Euclidean counterpart, the Schwinger functions. The use of Euclidean functional integrals contributed greatly to the progress of constructive field theory, which led in the 1970s and 1980s to the rigorous construction of renormalizable and super-renormalizable models in spacetime dimensions smaller than four and to many applications beyond the initial goals of the program.

Wightman never doubted that quantum field theories also exist in four dimensions and are relevant for physics. That deeply rooted conviction is perhaps best expressed in his September 1969 Physics Today article, "What is the point of so-called 'axiomatic field theory'?" (page 53). At a time when researchers were struggling to describe the ever-changing landscape of hadronic physics through dual models, bootstrap theory, *S*-matrix theory, and other approaches, the article contained a far-sighted defense of quantum field theory and of the rigorous axiomatic approach:

> [Axiomatic field theory] is incapable at present of calculating cross sections and is often thought to be obsessively mathematical. Nevertheless it offers a conceptual clarity indispensable for understanding the quantum mechanics of systems with an infinite number of degrees of freedom.
>
> Quantum field theory . . . is robust. It has had its ups and downs, but it somehow seems to survive all vicissitudes.

Four years later the discovery of quantum chromodynamics—the modern theory of the strong interactions—confirmed Wightman's view. Today, in our quest for a quantized theory of space, time, and gravitational forces, it is painfully clear how much in need we are of a new Wightman to define in clear mathematical terms the rules of the game.

I met Wightman toward the end of his scientific career, when he visited the École Polytechnique in 1977. The next year I followed him to Princeton. As a young student eager to work on constructive field theory, I was still far from grasping the breadth of Wightman's scientific culture and interests. During my first visit to his impressive Jadwin Hall office, filled from floor to ceiling with hundreds of books and binders of beautiful handwritten notes, he told me, "This semester I chose to lecture on one of the most central and difficult unsolved problems in mathematical physics . . ." He then enjoyed an intentional pause before completing his sentence with a smile: ". . . the formation of crystals!"

Wightman's last visit to Paris was to attend a conference in memory of his dear friend Louis Michel. Suddenly, there he was, tall as ever, walking down the large hall of the École Polytechnique in the glorious morning light, and I vividly remember young colleagues whispering: "Is this Arthur Wightman, really?"

Wightman died of Alzheimer's disease in Edison, New Jersey, at the Veterans Memorial Home, on 13 January 2013.

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