RETROSPECTIVE

Steven Weinberg (1933–2021)

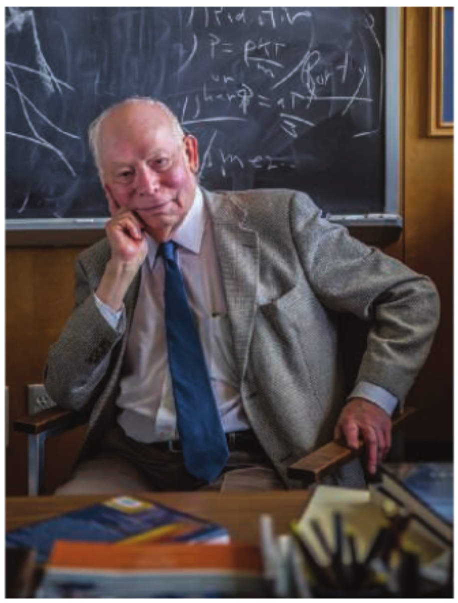
Titan of theoretical physics

By **John Preskill**

Steven Weinberg, widely regarded as the preeminent theoretical particle physicist of his era, passed away on 23 July at age 88. Steve took a pivotal step toward establishing what came to be known as the standard model of the fundamental particles and their interactions, for which he shared the 1979 Nobel Prize in Physics with Sheldon Glashow and Abdus Salam. That contribution was just one highlight in a career studded with major accomplishments. In later years, Steve authored a series of highly influential physics textbooks, as well as eloquent books and essays for the general public expounding on societal and scientific issues. He remained scientifically active up to his final days.

Born in New York City on 3 May 1933, Steve attended the Bronx High School of Science, which claims seven physics Nobel laureates among its alumni, including Steve's classmate Sheldon Glashow. He graduated from Cornell University in 1954 with a BA and received his PhD in physics from Princeton University in 1957, under the supervision of theoretical physicist Sam Treiman. After postdoctoral appointments at Columbia University and the University of California, Berkeley, Steve held faculty positions at Berkeley and the Massachusetts Institute of Technology before moving to Harvard University, where he was hired to fill the shoes of the departing Julian Schwinger. At the time of his death, he was the Jack S. Josey-Welch Foundation Chair in Science and Regental Professor at the University of Texas at Austin, where he had been director of the Theory Group since 1982.

At the start of Steve's career, particle physics was awash in new data, but theoretical understanding lagged behind. Twenty years later, the situation had changed completely. By then, all of nature's known fundamental forces, apart from gravitation, had been woven into a common framework, the standard model, which agrees with experiments in exquisite detail. A crucial step was Steve's "model of leptons," which provided a mathematically sensible description of how electrons interact with neutrinos. What makes that model work is an idea Steve "fell in love with" when he first encountered it in 1960: Nature respects exact symmetries that are hidden from our view because the physical states we encounter (including the vacuum state) are less symmetrical than the underlying physical laws. Steve's model predicted a kind of weak nuclear force never before seen, associated with a previously unknown fundamental particle called the Z boson. By the late 1970s, the existence of this new force had been firmly established experimentally, setting the stage for the Nobel Prize.



It is ironic that Steve's most famous contribution to physics is a concrete model. Constructing models was not his usual style—he preferred robust general arguments expressing solid truths that might survive even as particular models are found wanting and cast aside. Much more in character was another of Steve's groundbreaking achievements, formulating and advancing the idea known as effective field theory. A truly complete theory of fundamental physics would need to include massive particles and short-distance interactions that are still unknown because they are beyond the reach of currently feasible experiments. Steve exhorted physicists to write down an "effective theory" that incorporates all the essential principles, such as locality in space and time, conservation of probability, and all relevant symmetries that apply. Surprisingly, our ignorance about the more complete theory does not prevent us from making precise quantitative predictions about experiments performed at accessible energies. The success of this framework, in particle physics and beyond, is a vindication of Steve's credo that we should build our understanding of nature on the most general and trusted fundamental principles. While the roots of the effective field theory concept came from Kenneth Wilson, it was Steve who masterfully developed it into an efficient computational scheme and convinced other physicists of its power.

Steve had many distinctive qualities as a researcher. For one, he was not a visual thinker at all—Steve believed in the explanatory power of equations, not pictures. His otherwise lucid textbook *Gravitation and Cosmology*, published in 1972, contains hardly any figures, even though most physicists appreciate drawings that convey the geometry of spacetime. When MS-DOS was superseded by Windows, Steve migrated to the new operating system reluctantly, because he was much more comfortable typing on the command line than clicking an icon.

With a few exceptions, Steve was the sole author of his best-known papers, and he almost never collaborated directly with students. He usually worked at home, where only his wife, Louise, could interrupt him. Oddly, he kept a television on his desk, which was often turned on while he worked; he explained that this made it easier to resume the task at hand after taking a break. As my PhD adviser during the late 1970s, Steve was a fount of inspiration more than a source of concrete guidance (which was fine with me). My explorations of the very early Universe and of particle physics beyond the standard model followed in his footsteps.

Although he never stopped conducting high-quality original research, Steve also excelled at writing physics textbooks that blended uncommon insight with meticulous attention to detail. His extensive writings for the lay public often staked out controversial positions on subjects such as nuclear proliferation, religion, the history of science, and funding for big science projects. Whatever the topic, his clear arguments and deep scholarship never failed to impress and edify.

Steve believed in the power of the human mind to understand the world. He sometimes mused about how astonishing it is that a theorist's "squiggles" on paper can align with physical reality. And yet they can. Few squiggles have captured nature's hidden secrets better than those written by the hand of Steven Weinberg. ■

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