Yoichiro Nambu

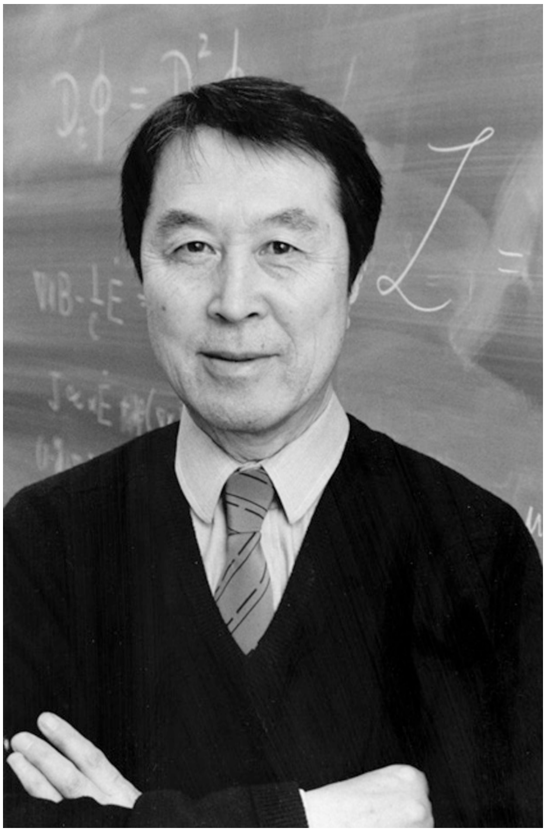
(1921–2015)

Visionary theorist who shaped modern particle physics.

Yoichiro Nambu was one of the most influential theoretical physicists of the twentieth century. His deep and unexpected insights often took years for others to understand and fully appreciate. They include: spontaneous symmetry breaking, for which he was awarded half of the 2008 Nobel Prize in Physics; the theory of quarks and gluons; and string theory.

Modern particle theory is defined by its accomplishments, largely embodied in the standard model of the strong, weak and electromagnetic interactions, and by its aspirations — a theory that unifies all the forces and particles. Nambu's contributions to symmetry breaking and the theory of quarks form the foundation of the standard model, and string theory is the most promising approach to a theory of everything.

Nambu, who died of a heart attack on 5 July in Osaka, Japan, was born in Tokyo in 1921. It was the year that Yoshio Nishina visited Copenhagen and brought back quantum mechanics to Kyoto, Japan's first foray into modern physics. The 'Copenhagen in Kyoto' school included Hideki Yukawa, who won the 1949 Nobel prize for his prediction of the existence of mesons, and Sin-Itiro Tomonaga, who shared the 1965 Nobel prize for his work in quantum electrodynamics, the theory that describes all of electromagnetism from chemistry to lasers.



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Nambu attended the University of Tokyo, graduating with a master's degree in physics in 1942. His studies were interrupted by the Second World War. In the army he dug trenches and worked on the Japanese radar project, but his mind was on fundamental physics. In 1945, he married his assistant, Chieko Hida.

Under difficult post-war circumstances, always hungry and living in his office at the University of Tokyo, Nambu finished his PhD in 1952. Although his department's research focus was condensed-matter physics, Nambu was drawn to nuclear and particle physics and he attended seminars on these topics by Nishina, Tomonaga and Yukawa at the nearby Tokyo University of Education.

In 1950, Tomonaga recommended Nambu for a faculty position at Osaka City University, where he wrote two remarkable papers. He derived the now-famous Bethe–Salpeter equation that describes the quantum theory of how particles bind together (Y. Nambu *Prog. Theor. Phys.* **5,** 614–633; 1950). And he proposed how the newly discovered 'strange' particles were produced (Y. Nambu *et al. Prog. Theor. Phys.* **6,** 615–619; 1951). Each paper pre-dated by a year its more well-known counterpart written by US physicists.

Nambu's big break came in 1952 when, at Tomonaga's suggestion, he was invited by Robert Oppenheimer to the Institute for Advanced Study in Princeton, New Jersey. Years later he described that experience as overwhelming — he felt surrounded by people smarter and more aggressive than him. Nonetheless, physicist Murph Goldberger thought highly enough of him to invite him to the University of Chicago, Illinois, in 1954.

In particle physics, Chicago was the place to be just after the Second World War. Enrico Fermi was the intellectual leader of a physics department that included more than ten future Nobel prizewinners. Nambu spent the rest of his academic career — more than half a century — at the university's Enrico Fermi Institute.

With Giovanni Jona-Lasinio in 1961, Nambu introduced the idea of hidden or broken symmetries while trying to understand superconductivity — the resistanceless flow of electric current at very low temperatures. Mathematical symmetries in Maxwell's theory of electromagnetism are hidden at very low temperatures, as is the symmetry between the electromagnetic and weak forces, the hallmark of the electroweak theory. The Higgs boson, discovered in 2012 at CERN, Europe's particle-physics laboratory near Geneva, Switzerland, reveals the fact that the electroweak symmetry is broken.

In 1964, George Zweig and Murray Gell-Mann each independently proposed the idea of quarks to explain the hundreds of new elementary particles that were being discovered at particle accelerators. It took more than 20 years to sort out quarks' properties and how they are held together in triplets and pairs by a 'colour' force mediated by gluons to form protons, neutrons, mesons and other particles. But Nambu and Moo-Young Han put most of it together in 1965. As Gell-Mann said: "He did this … while the rest of us were floundering." In an attempt to better understand the colour force, Nambu went on to co-invent string theory.

I had the good fortune of being Yoichiro's colleague for more than 30 years. He was surprisingly soft-spoken and modest for someone so wise and important. We all listened carefully to anything he had to say, but rarely fully comprehended it. "People don't understand him, because he is so far-sighted," Edward Witten of the Institute for Advanced Study once said.

A downside of being so ahead of the times is that recognitions come slowly. After years of hoping, we were ecstatic when he received the Nobel prize. Nambu could not travel to the ceremony in Stockholm, so the Swedish ambassador to the United States came to Chicago to present the modest giant of particle physics with his prize at ceremony attended by 200 of his friends and colleagues. A more joyful event I cannot remember. ■

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