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Philip W. Anderson, Nobel Laureate in Physics, Is Dead at 96

His work at Princeton and Bell Labs deepened science's understanding of magnetism, superconductivity and the structure of matter.

By Scott Veale

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Philip W. Anderson, an American physicist whose explorations of electronic behavior in solid materials like glass, crystals and alloys led to a Nobel Prize and deepened science's understanding of magnetism, superconductivity and the structure of matter, died on Sunday in Princeton, N.J. He was 96.

His daughter, Susan Anderson, confirmed the death.

"Anderson was the pre-eminent condensed-matter theorist of his day — a day that lasted for over 50 years — and his fingerprints are everywhere," Nigel Goldenfeld, a physics professor at the University of Illinois at Urbana-Champaign, said by email.

Condensed-matter, or solid-state, physics focuses on the properties of solids and liquids with high densities of atoms that constantly interact with one another; by contrast, particle physics deals with subatomic particles. Much of Dr. Anderson's most influential work concentrated on randomly structured, or "disordered," materials that lack the regular crystalline composition of most matter.

He was particularly interested in the behavior of electrons within these disordered materials, which include certain kinds of semiconductors. In 1958, he published a paper in which he showed how electrons in disordered materials can either move freely or become fixed in a specific position, as if stuck in glue, depending on the degree of disorder. His finding of how electrons behave when trapped, or localized, became known as Anderson localization, and was subsequently extended to the properties of light and sound waves.

"This is foundational physics that completely shook up physics at a time when it was still thought that electrons and waves in general are always de-localized," Piers Coleman, a physics professor at Rutgers University, said by email, adding that Anderson localization explains, among other things, how light is reflected backward in fog and why disordered metals become insulators.

Dr. Anderson received the 1977 Nobel Prize in Physics, along with Nevill Francis Mott of Britain and the American John Hasbrouck van Vleck, "for their fundamental theoretical investigations of the electronic structure of magnetic and disordered systems," as the Nobel citation read.

Dr. Anderson, left, received his share of the Nobel Prize from King Carl Gustaf of Sweden during a ceremony in Stockholm in December 1977. “Anderson was the pre-eminent condensed-matter theorist of his day — a day that lasted for over 50 years,” a colleague said. Peter Knopp/Associated Press

Together with the renowned physicist Sam Edwards at the University of Cambridge, Dr. Anderson also conducted pioneering research into spin glasses, a class of materials whose complex magnetic behavior has provided an analogy for understanding other phenomena.

“Spin glasses are systems where atoms in a material, variables in a computer, or neurons in a brain interact with each other in partly structured, partly random ways,” Cristopher Moore, a physicist at the Santa Fe Institute, a research center in New Mexico dedicated to the interplay of social and physical sciences, said by email. Dr. Anderson once called spin glasses a “bridge between biology, statistical mechanics, and computer science.”

During the 1960s and '70s, Dr. Anderson explored the theory of superconductivity, in which certain alloys and metals lose all resistance to electrical currents at temperatures near absolute zero. Later in his career, he turned to high-temperature superconductors, which operate at higher temperatures — though still frigid — than traditional superconductors, resulting in more efficient electrical transmission.

Just as important as Dr. Anderson's technical achievements were his tireless — at times, feisty — advocacy for condensed-matter physics, which have come to dominate the profession, and the role of complexity in science.

"He was a brilliant intuitionist" who "gave depth and intellectual coherence to an entire field," said Andrew Zangwill, a physics professor at Georgia Tech, who is writing a biography of Dr. Anderson.

In 1972, Dr. Anderson stirred up the physics world with an article in the journal Science called "More Is Different," which became part of a spirited debate about the widely accepted concept of reductionism in science. Reductionism maintains that everything can be reduced to a few fundamental laws describing the particles that are the basic constituents of matter.

Dr. Anderson focused instead on the limitations of reductionism, arguing that in certain materials entirely different properties emerge when enough individual particles — whether atoms or molecules — are collected together. A single copper atom, for example, has little electrical charge, but millions of copper atoms gathered in a wire can conduct electricity.

His colleague Murray Gell-Mann, who died last May, liked to disparage Dr. Anderson's field as "squalid state physics," reflecting the notion that particle physics, Dr. Gell-Mann's specialty, was a purer and superior endeavor.

Phillip Warren Anderson was born on Dec. 13, 1923, in Indianapolis to Harry Warren Anderson and Elsie Eleanor (Osborne) Anderson and grew up on a farm in Urbana, Ill. His father was a professor of plant pathology at the University of Illinois, Urbana-Champaign; and his mother, a homemaker, was the daughter and sister of professors at Wabash College in Indiana. "On both sides my family were secure but impecunious Midwestern academics," Dr. Anderson wrote in his Nobel biography.

He attended Harvard University but interrupted his studies during World War II to help build antennas for the Naval Research Laboratory in Washington. After the war he returned to Harvard, where he studied under Dr. van Vleck and completed his doctorate in 1949.

After graduating, he joined Bell Telephone Laboratories, based in Murray Hill, N.J., where he worked for more than 30 years, making several discoveries that contributed to his Nobel Prize, including Anderson localization.

In 1962, during his early work with superconductivity, Dr. Anderson published a paper on how photons — the quantum packets of energy that transmit light — acquire mass inside a superconductor. Two years later, his work was cited by Peter Higgs in his theory predicting the existence of an elusive particle that endows other fundamental particles with mass — an idea confirmed in 2012 with the discovery of the Higgs boson, or "God particle."

In the late 1960s, Dr. Anderson taught part-time at the University of Cambridge in England, and in 1975 joined the department of physics at Princeton University. He retired from Bell Labs in 1984 to become a full-time professor at Princeton, and in 1996 was named the Joseph Henry professor of physics emeritus.

He received the National Medal of Science in 1982, along with membership in the Royal Society and an honorary fellowship at Jesus College, Cambridge. In addition, he was a longtime adviser and collaborator at the Santa Fe Institute.

In 1947 he married Joyce Gothwaite. In addition to his daughter, Dr. Anderson is survived by his wife and three nephews.

Dr. Anderson was aware of how daunting his research could appear to outsiders. In 2011, he published a collection of essays, lectures and other writings, "More and Different: Notes From a Thoughtful Curmudgeon," in which he recalled "the recurring nightmare-like feeling I have when a layman asks me, "Just exactly what did you do to earn the Nobel Prize, Dr. Anderson?"

He was also a first-degree master of the Japanese board game Go. W. Brian Arthur, an economist and professor at the Santa Fe Institute, recalled one evening in the 1990s when a group of colleagues from the institute were discussing board games at a local restaurant, and he asked Dr. Anderson if he played any.

"'Well, I play a bit of Go,' he said," Professor Arthur recalled. "I pressed him. 'Are you any good at it, Phil?' 'Yes,' he said. 'How good?' 'Well, there are four people in Japan who can beat me.' Then a long silence. 'But they meditate,' he added."

Correction: March 31, 2020
An earlier version of this obituary misspelled the middle name of Dr. Anderson's mother. She was Elsie Eleanor Anderson, not Elinore.

A version of this article appears in print on March 31, 2020, Section A, Page 24 of the New York edition with the headline: Philip Anderson, 96, Physicist Who Won Nobel for Electron Insights, Dies