# J. Robert Schrieffer

## *(1931–2019)*

### Physicist who shared Nobel for theoretical basis of superconductivity.

The story of how Robert Schrieffer solved a problem that had resisted the best minds in physics for more than 40 years, while riding the New York subway, is the stuff of legend in some circles. His explanation of how superconductivity works earned him a share of the 1972 Nobel Prize in Physics. A former president of the American Physical Society (APS), Schrieffer died on 27 July, aged 88.

In 1911 it was discovered that certain metals, when cooled to low enough temperatures, can carry current with no resistance. This seemingly miraculous property, superconductivity, arises directly from quantum mechanics, and underlies many contemporary technologies, such as magnetic resonance imaging body scanners and particle accelerators. For decades, however, there was no theory to explain how electrons in superconducting materials overcome their own mutually repulsive properties and other causes of resistance.

In early 1957, Schrieffer, then a 25-year-old graduate student, wrote down a quantum-mechanical wave function that accounted for the behaviour of electrons in superconductors. With his thesis adviser John Bardeen and postdoc colleague Leon Cooper, he published the now-famous BCS wave function and the full theory of superconductivity less than a year later — named BCS after the trio, who shared the Nobel prize (J. Bardeen, L. N. Cooper and J. R. Schrieffer *Phys. Rev*. **108**, 1175; 1957). The work has had far-reaching consequences for both fundamental science and practical technology. Schrieffer continued to make foundational contributions to our understanding of electrons in solids.

Born in Oak Park, Illinois, in 1931, Schrieffer studied physics at the Massachusetts Institute of Technology in Cambridge as an undergraduate. It was at graduate school at the University of Illinois at Urbana-Champaign that he began working with Bardeen, who in 1956 had just won a share of the physics Nobel for the invention of the transistor.

Bardeen suggested Schrieffer try his hand at understanding superconductivity. This was a risky proposition. After the initial success of quantum theory in describing ordinary conductors, insulators and semiconductors, there had been countless attempts to explain superconductors and all had failed. But the timing was right. Bardeen, with his then-postdoc David Pines, had studied the effect of phonons (quantized sound waves) on metals, showing that they mediated an attractive interaction between electrons. Cooper found that this attractive interaction could lead to the formation of bound pairs of electrons. However, Cooper's theory described only the formation of a single electron pair. The question remained how to describe the many electrons pairing in the full electronic state of the metal, and why such pairing would lead to the properties of a superconductor.

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Schrieffer's intuitive leap came to him on the subway while attending an APS meeting in 1957. It struck him that a natural wave function for describing a state with electron pairing was one in which the number of electrons was not fixed, but had a certain quantum mechanical uncertainty. He wrote it down there and then. This key insight, radical at the time but now part of the standard toolkit of theoretical physics, cracked the problem wide open. With the wave function in hand, it quickly became possible to calculate many of the observed properties of superconductors, and to predict new properties, which were subsequently found.

Schrieffer's beautiful idea has contributed to many branches of fundamental physics. In condensed-matter physics, it has also been applied to superfluid helium-3 and cold-atom systems. Elsewhere, the theory has helped to explain complex nuclei and neutron stars, and played a crucial part in establishing the understanding of quantum field theory that underlies today's standard model of strong, electromagnetic and weak interactions.

Schrieffer went on to take postdoctoral positions at the Niels Bohr Institute in Copenhagen and at the University of Birmingham, UK. He held faculty positions at the University of Chicago, the University of Illinois and the University of Pennsylvania.

Throughout his career, Schrieffer displayed the same flair as in his brilliant wave function insight. In 1979, he and his colleagues showed that certain conducting polymers could exhibit excitations with electrical charge, but no spin (the magnetic moment of each electron is called its spin). The opposite could also occur: excitations could have spin, but no charge. It was a revelation that the two fundamental properties of electrons, charge and spin, could be split apart. This deconstruction has since been discovered at many other frontiers of condensed-matter physics. A later collaboration showed that a second example of deconstructed electrons, the fractionally charged excitations in the fractional quantum Hall states, also exhibit fractional statistics, meaning that they are not the conventional bosons or fermions that were thought to divide all fundamental particles into two classes.

In 1980, he moved to the University of California, Santa Barbara, and joined the newly formed Institute for Theoretical Physics. Here, between 1984 and 1989, he served as its second director, helping to establish its strong reputation as a centre for theoretical physics research. His final move in 1992 was back to Florida, where he took a state-wide professorial position in the Florida State University System. From that year until 2006 he was the first chief scientist of the National High Magnetic Field Laboratory at Florida State University in Tallahassee, where he had a crucial role in establishing the new facility's scientific credentials. His 1996 APS presidency was marked by his efforts to improve communication between the physics community and the public, and between physicists themselves to help unify the field.

Schrieffer was equally known for his warmth, charm, generosity and brilliance. When Bob discussed physics, his eyes would twinkle and a boyish demeanour would shine through. This enthusiasm and provision of wise counsel to younger physicists never waned. His unique style is captured, as if in a photograph, by the BCS wave function. ■

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