BUSH CONFERS HIGHEST US GOVERNMENT HONORS IN SCIENCE AND TECHNOLOGY

At a ceremony last November, President Bush presented 20 National Medals of Science and 11 National Medals of Technology to a group of scientists and engineers assembled in the East Room of the White House.

The recipients of the science award included George F. Carrier, T. Jefferson Coolidge Professor of Applied Mathematics Emeritus at Harvard University; Allan M. Cormack, University Professor at Tufts University; Mildred S. Dresselhaus, Institute Professor at the Massachusetts Institute of Technology; Nick Holonyak Jr, Center of Advanced Study Professor of Electrical and Computer Engineering at the University of Illinois at Urbana–Champaign; Edwin M. McMillan, professor of physics emeritus at the University of California, Berkeley; Robert V. Pound, Mallinckrodt Professor of Physics Emeritus at Harvard University; and Roger D. Revelle, director emeritus of the Scripps Institution of Oceanography at the University of California, San Diego.

The following were among those who received technology medals: John V. Atanasoff, retired founder of Cybernetics Inc; Marvin Camras, research professor of electrical and computer engineering at Illinois Institute of Technology; Jack St. Clair Kilby, a consultant living in Dallas, Texas; Gordon E. Moore, chairman of Intel Corporation; and Chauncey Starr, president emeritus of the Electric Power Research Institute in Palo Alto, California.

Carrier was cited for "achievement and leadership in the mathematical modeling of significant problems of engineering science and geophysics, and their solution by the application of innovative and powerful analytical techniques." Carrier has contributed to viscometry, gyroscopy and centrifugal-force separation, and has helped solve problems of atmospheric reentry for space vehicles. Carrier wrote a series of papers on combustion that was particularly relevant to internal combustion engines, and he has studied a wide range of phenomena involving the dynamics of the oceans. His work on the mechanics of water waves has been useful to the shipping industry, and he has produced particularly broad and detailed analyses of the interactions of hurricanes with the land and sea. Most recently, Carrier has studied large fires, firestorms and "nuclear winter."

Carrier received his PhD in applied mechanics from Cornell University in 1944. He was on the faculty of the division of applied mathematics at Brown University from 1946 to 1952, when he became Gordon McKay Professor of Mechanical Engineering at Harvard University. Carrier became the Coolidge Professor of Applied Mathematics in 1972. He has been an emeritus professor since 1988.

Cormack was recognized for "his scientific work, including the development of computer-assisted tomography," and for his work "as a scholar and teacher, especially of undergraduates." In 1963 and 1964 Cormack developed the theory by which x-ray transmission data of a sample could be deconvoluted to yield a cross-sectional map of the sample's x-ray absorptivity. Cormack confirmed experimentally that such maps, or "tomograms," could be created, and he suggested their potential value for making medical diagnoses. This work spawned the now widely used medical imaging method of computerized axial tomography and earned Cormack the Nobel Prize in Physiology or Medicine, which he shared with Godfrey N. Hounsfield in 1979.

Cormack received his MSc in physics in 1945 from the University of Cape Town in South Africa. He was a lecturer at Cape Town from 1950 to 1956, and he joined the physics faculty at Tufts University in 1957. Cormack has been a University Professor of Physics at Tufts since 1980.

Dresselhaus received the medal of science for "her studies of the electronic properties of metals and semimetals, and for her service to the nation in establishing a prominent place for women in physics and engineering." Using a variety of transport, optical and magneto-optical techniques, Dresselhaus has made major theoretical contributions to the understanding of the electronic structure of semimetals, including bismuth and graphite—both with and without intercalants. In studies of staging in graphite intercalation compounds, Dresselhaus learned much about the relationship between the structural and electronic properties of these materials. She spent the early part of her career studying conventional superconductors, and has recently turned to research on high-temperature superconductors. Both as a woman professor and as one of the two women to serve as president of The American Physical Society, Dresselhaus has encouraged many women to pursue careers in science and engineering.

Dresselhaus received her PhD in physics from the University of Chicago in 1958. She was on the staff of MIT's Lincoln Laboratory from 1960 to 1967, and then became a professor in the MIT department of electrical engineering. In 1973 she became permanent holder of the Mauze Chair. From 1977 to 1983 she served as director of the MIT Center for Materials Science and Engineering. Dresselhaus has been an Institute Professor at MIT since 1985.

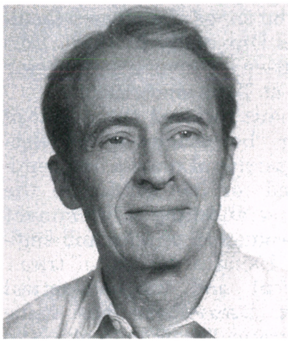
Holonyak was recognized for his

"contributions as one of the nation's most prolific inventors in the area of semiconductor materials and devices, and for his role as research mentor while working at the forefront of solid-state science and technology." During the period 1957–63 Holonyak, with Richard Aldrich, invented the shorted-emitter and symmetrical silicon-controlled rectifier and thyristor switches. In the same period he accomplished the first observation of inelastic tunneling, which constituted the beginning of tunneling spectroscopy. And his studies of GaAsP, coupled with his work in constructing a visible-spectrum laser and the first p–n junction in an alloy crystal system, made possible the production of GaAsP light-emitting diodes. Since 1976 Holonyak has mostly studied quantum-well light emitters and lasers, and impurity-induced layer disordering.

Holonyak was John Bardeen's first graduate student, and received his PhD in electrical engineering from the University of Illinois, Urbana–Champaign, in 1954. From 1957 to 1963 he worked at the Advanced Semiconductor Laboratory of the General Electric Company in Syracuse, New York. Since 1963 Holonyak has been a professor in the department of electrical and computer engineering and in the materials research laboratory at the University of Illinois, and since 1977 has been a professor in the University of Illinois Center of Advanced Study.

McMillan was honored for his "scientific achievements including the identification of the first transuranic element (neptunium) and the invention of the phase-stability principle incorporated in the synchrotron." In the early part of his career, McMillan devised improvements in ion sources, magnetic field shaping, beam extraction, and power and control systems in cyclotrons. After observing an unknown isotope in a fission experiment, McMillan, with Philip Abelson, chemically identified the substance as an isotope of the new element 93, which McMillan called "neptunium." McMillan and Glenn T. Seaborg shared the Nobel Prize in Physics in 1951 for their discoveries in the chemistry of the transuranium elements. During World War II McMillan worked on microwave radar, invented and developed an underwater echo

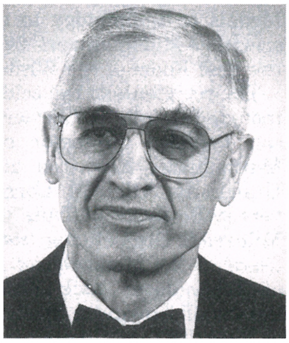
George T. Carrier



Allan M. Cormack

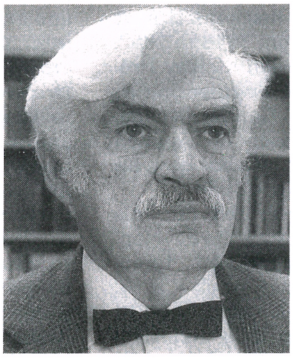
Mildred S. Dresselhaus

Nick Holonyak Jr



Edwin M. McMillan

Robert V. Pound



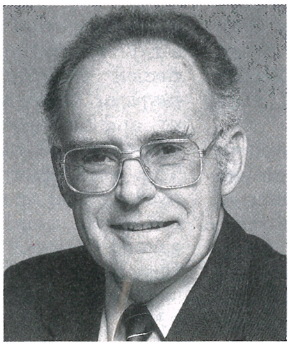
Roger D. Revelle

John V. Atanasoff

Marvin Camras

Jack St. Clair Kilby

Gordon E. Moore



Chauncey Starr

repeater, and assumed broad technical and administrative responsibilities in the Manhattan Project. In 1945 he came up with the principle of phase stability, which allows particle accelerators to reach arbitrarily high energies provided that the energy is increased adiabatically, so that at any moment the ions occupy stable, zero-energy-gain orbits.

McMillan received his PhD in physics from Princeton University in 1932. In 1934 he joined the physics faculty at the University of California, Berkeley. From 1958 until his retirement in 1973 McMillan was director of the Lawrence Berkeley Laboratory.

Pound was cited for his "pioneering experiments in nuclear magnetic resonance, including the study of quadrupole interactions and negative spin temperatures, and for the demonstration of the gravitational shift of gamma-ray photons." Pound's work on nmr dates back to 1945, when he and his MIT colleagues Edward M. Purcell and Henry C. Torrey made the first successful detection of nmr in condensed matter. At Harvard, with Purcell and Nicolaas Bloembergen, Pound studied nmr in liquids and gases, and developed the theory of fluctuation narrowing caused by thermal motions. Pound also disovered nuclear electric quadrupole interactions in crystals. In 1949 Pound developed a method of nuclear alignment based on nuclear quadrupole interactions, and in 1950, with Purcell, he introduced the idea of negative spin temperatures. With Glen A. Rebka Jr, and later with Joseph L. Snider, Pound measured the gravitational redshift of gamma rays using the Mössbauer effect. Pound and Rebka also predicted and experimentally confirmed the temperature dependence of gamma-ray energy due to the relativistic time dilation associated with thermal vibration.

Pound received his BA in physics in 1941 from the University of Buffalo. During World War II he worked first at the Submarine Signal Company in Boston and then at MIT's Radiation Laboratory. He moved to Harvard University in 1946 and became an assistant professor of physics there in 1948. In 1968 Pound became Mallinckrodt Professor of Physics, and from 1968 to 1972 Pound served as chairman of Harvard's physics department. From 1975 to 1983 he was director of Harvard's physics laboratories. He became an emeritus professor in 1989.

Revelle was recognized for his "pioneering work in the areas of carbon dioxide and climate modification, oceanographic exploration presaging plate tectonics, and the biological effects of radiation in the marine environment, and studies of human population growth and global food supplies."

After receiving his PhD in oceanography from the University of California, Berkeley, in 1936, Revelle began a 28-year period of employment as a research assistant and faculty member at the Scripps Institution of Oceanography in La Jolla, California. He was the director of the institution during the period 1950–64, for four years of which he was also the dean of the school of science and engineering at the University of California, San Diego. In 1964 Revelle accepted a position as Richard Saltonstall Professor of Population Policy and director of the Harvard Center for Population Studies at Harvard University.

While at Scripps, Revelle led a number of expeditions into the deep Pacific to study oceanic processes and the sea floor. In the early 1960s Revelle became interested in studying the interactions among the rapidly growing populations of less developed countries, their natural resources and their environment. Revelle has also had a prominent voice in the dialogue over how to manage the rising levels of atmospheric carbon dioxide caused by the burning of fossil fuels.

[In July, Revelle died of complications from cardiac arrest. An obituary will appear in a future issue of PHYSICS TODAY.]

Atanasoff received the technology medal for his "invention of the electronic digital computer, and for contributions toward the development of technically trained US work force." As a young professor of mathematics and physics at Iowa State College (now Iowa State University), Atanasoff sought a quick electronic method for doing the tedious numerical computations that then consumed many hours of graduate student time. In 1939 the Iowa State College Research Council granted Atanasoff $650 to build a prototype electronic calculating machine. The completed machine, first demonstrated in 1939 and called the Atanasoff–Berry Computer, was the first electronic digital computer.

Atanasoff received his PhD in theoretical physics from the University of Wisconsin in 1930. He taught at Iowa State College until 1942, when he joined the US Navy Ordnance Laboratory as chief of the acoustics division. In 1949 he became chief scientist of the US Army Field Forces. From 1949 to 1952 Atanasoff directed the fuse program at NOL. In these capacities, sometimes under wartime pressures, Atanasoff visualized many solutions and developed many models for problems in seismology, acoustics and ballistics. Final solutions to the problems required training in new areas of technology, and were often deceptively simple.

In 1952 Atanasoff left NOL to form the Ordnance Engineering Company, which became part of Aerojet General Corporation in 1956. Atanasoff was vice president of Aerojet until 1961, when he formed Cybernetics Inc.

Camras was recognized for "the development and commercialization of magnetic recording resulting in the creation of a new industry with over 125 licenses producing products such as audio and video cassettes, broadcast sound video, tapes and disks for computer memories, and magnetic sound for motion pictures." In the 1930s, while a student as the Armour Institute of Technology (which later became part of the Illinois Institute of Technology), Camras built a wire recorder. Since then he has earned more than 500 patents for inventions in audio and video recording and computer data storage. His work during World War II included the introduction of a method for reducing noise and distortion in audio recordings by high-frequency bias, and the development of a ferric oxide compound for magnetic tape.

Camras earned his BS in 1940 from the Armour Institute of Technology and his MS in 1942 from ITT. In 1940 he began work as a physicist at the IIT Research Institute; he became the senior scientific adviser at the institute in 1969.

Kilby was honored for his "invention and contributions to the commercialization of the integrated circuit and the silicon thermal print-head; for his contributions to the development of the first computer using integrated circuits; and for the invention of the hand-held calculator and gate array." In 1958, during his first few months working for Texas Instruments in Dallas, Kilby conceived of and built the first electronic circuit in which all elements—resistors, capacitors and transistors—lay on a single semiconductor wafer. About half the size of a paper clip, Kilby's device was the first integrated circuit, or "microchip." In the 1960s Kilby led Texas Instruments research teams that developed the first guidance computer for the Minuteman II missile and the first computer incorporating integrated circuits. He later coinvented the electronic hand-held calculator and the thermal printer, two widely used applications of integrated circuit technology.

Before entering college, Kilby served in the armed forces during world war II. He was initially assigned to the US Army Signal Corps, but later volunteered for special service, and ultimately found his way into the Office of Strategic Services. He received his bachelor's degree in 1947 from the University of Illinois and his master's degree in 1950 from the University of Wisconsin, both in electrical engineering. Kilby then worked for the Centralab division of Globe Union Inc. in Milwaukee from 1947 to 1958. He joined TI in 1958 and became an assistant vice president in 1968. In 1970 he took a leave of absence from TI to do consulting work.

Moore was recognized for "his seminal leadership in bringing to American industry the two major postwar innovations in microelectronics—large-scale integrated memory and the microprocessor—that have fueled the information revolution." In 1957 Moore, along with a handful of other young scientists who worked together at Shockley Transistor Corporation, founded Fairchild Semiconductor Corporation in Mountain View, California. At the company's inception Moore became manager of the engineering department, and two years later he became the director of research and development. During the next decade Fairchild, under Moore's leadership, produced the first commercial integrated circuit. In 1968 Moore, with his Fairchild colleague Robert Noyce, founded Intel Corporation to develop and manufacture products containing large-scale integrated circuits—beginning with semiconductor memories. Intel went on to produce, among other things, the world's first microprocessor.

Moore received his PhD in chemistry and physics from Caltech in 1954. When Intel was founded, Moore was the company's executive vice president. In 1975 he became president, and in 1979 chairman of the board.

Starr received his technology medal for "his original contributions to energy production and policy; for pioneering in nuclear power; for developing risk assessment and risk management concepts; for organizing the Electric Power Research Institute, a consortium; for leadership in engineering and contributions to a technically trained US work force."

Starr received his PhD in physics from Rensselaer Polytechnic Institute in 1935. After a research fellowship at Harvard University and a three-year period spent working in cryogenics at MIT, Starr joined the

Manhattan District at the Radiation Laboratory of the University of California, Berkeley and at Oak Ridge.

After World War II Starr went to Rockwell International, where he was a leader in the development of nuclear propulsion for rockets and ramjets and of miniature nuclear reactors for use in space, as well as in the design of nuclear power plants.

Over the next 20 years, he rose to become vice president of Rockwell and president of its Atomic International division. From 1967 to 1973 Starr was the dean of the school of engineering and applied science at the University of California, Los Angeles. While at UCLA, Starr published seminal papers in risk analysis.

Starr left UCLA to become the founding president and vice chairman of the Electric Power Research Institute, started in 1973 by the electric utilities to conduct technology development. He is now president emeritus.

OBITUARIES

John S. Bell

John Stewart Bell died suddenly of cerebral hemorrhage on 1 October 1990, at the age of 62. The loss to physics, and to natural philosophy in general, is irreparable, for Bell not only made the most profound contribution of his generation to the foundations of quantum mechanics but had continued to explore new ideas on the subject.

John Bell was born in Belfast, Northern Ireland, into a working-class family. Since free secondary education was not provided at the time of his youth, he was able to continue school after age 14 only because a special fund was raised for him. At Queen's University in Belfast, he earned one BSc degree in experimental physics (1946), followed by another in mathematical physics (1949). In 1949 he joined the Atomic Energy Research Establishment at Malvern and Harwell, where he initially worked on nuclear reactors for some months before turning to theoretical work on particle accelerators. On leave from AERE, he worked in 1953–54 on quantum field theory at the University of Birmingham. He returned to AERE, Harwell, in 1954, and continued his researches on field theory and nuclear theory until 1960, meanwhile receiving a PhD at the University of Birmingham (1956). At Malvern he met Mary Ross, also an accelerator physicist, whom he married in 1954. From 1960 onward both John and Mary Bell were on the staff of CERN.

In a sense John Bell had two careers. He contributed directly to the main mission of CERN by his research in nuclear physics, field theory, elementary-particle theory and accelerator design. But he also studied the foundations of quantum mechanics with great intensity, even though he jokingly referred to this work as his "hobby." His delightful exposition "Bertlman's Socks and the Nature of Reality" resulted from his attempt to explain his hobby to one of his collaborators in field theory. That article, together with other related papers by Bell, was reprinted in *Speakable and Unspeakable in Quantum Mechanics* (Cambridge University Press, 1987).

As an undergraduate Bell was already dissatisfied with textbook presentations of quantum mechanics, and was particularly disturbed by Niels Bohr's thesis that a measuring apparatus must be described classically and not treated quantum mechanically. Bell felt that there should be a unified description of the physical world applying to both microscopic and macroscopic systems. While at Birmingham, Bell was intrigued by two papers written by David Bohm in 1952, proposing a hidden-variables interpretation of quantum mechanics, which seemed a promising way to achieve the desired unification. According to Bohm's construction, something was amiss in John von Neumann's oft-cited demonstration of the impossibility of a hidden-variables interpretation. Bell seriously turned his attention to this matter after attending Josef Jauch's seminar in 1963 at the University of Geneva on the foundations of quantum mechanics. In his paper entitled "On the Problem of Hidden Variables in Quantum Mechanics," Bell proved the impossibility of simple hidden-variables theories, without relying on a dubious premise that von Neumann had used. In the same paper Bell also pointed to a more complex family of hidden-variables theories (later called "contextual") that are not excluded by his own theorem.

John S. Bell

The fact that Bohm's construction required a kind of "action at a distance" between spatially separated particles led Bell to pose a penetrating and fruitful question: Is it possible for a hidden-variables theory to recover all the statistical predictions of quantum mechanics without postulating action at a distance? His negative answer to this question was published in 1964 in a paper called "On the Einstein–Podolsky–Rosen Paradox." The remarkable result contained therein is now commonly called Bell's theorem. To prove this theorem Bell first showed that any hidden-variables theory that abstains from action at a distance implies that the correlations between pairs of observables of spatially separated particles must obey a certain inequality, subsequently known as Bell's inequality. Then he showed that this inequality is violated by the predictions of quantum mechanics for a pair of spatially separated spin-$\frac{1}{2}$ particles in the singlet spin state. (Later work showed many other quantum mechanical violations of Bell's Inequality.)

Over the last two decades more than a dozen experiments inspired by Bell's work have shown that nature violates Bell's inequality but agrees with quantum mechanics. As a result of these experiments Bell accepted that nature must be in some sense "nonlocal" in a way that Einstein almost certainly would have found uncongenial. Nevertheless, Bell still did not accept Bohr's interpretation of quantum mechanics, and he continued to investigate reinterpretations and modifications that would achieve his vision of a unified microscopic–macroscopic physics, entirely free of anthropocentrism. For example, one paper, "Beables for Quantum Field Theory," presents an explicitly "nonlocal" hidden-variables theory, and another, "Are There Quantum Jumps?" explores a stochastic modification of the time-dependent Schrödinger equation.

Several qualities made Bell the generally acknowledged leader of research on the foundations of quantum mechanics in the last two decades: a