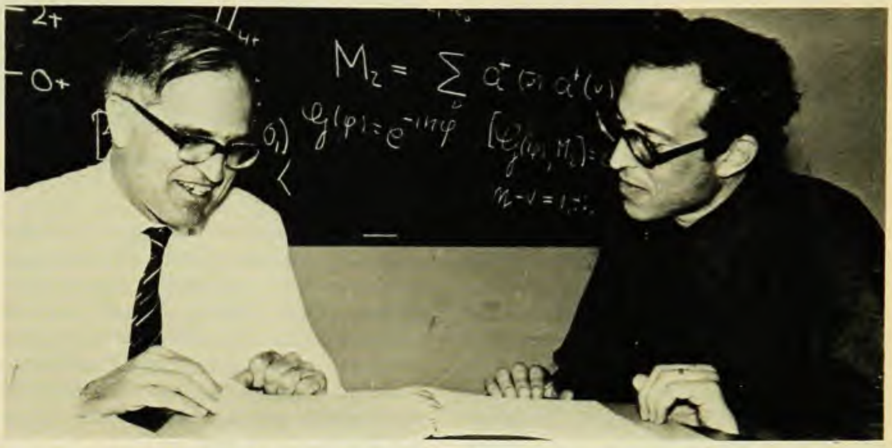
Bohr, Mottelson and Rainwater win Nobel physics prize

The 1975 Nobel Prize in physics has been awarded by the Royal Swedish Academy of Sciences to Aage Bohr, Ben Mottelson and James Rainwater for "the discovery of the connection between collective motion and particle motion in atomic nuclei and the development of the theory of the structure of the atomic nucleus based on this connection."



Aage Bohr (left) and Ben Mottelson working in Copenhagen on the nuclear collective model.

The collective model, developed by the three men, was a unification of the shell model with the liquid-drop model, which had been proposed by Aage Bohr's father, Niels, in 1936. (Niels Bohr, of course, was also a Nobel laureate in physics, in 1922, "for his services in the investigation of the structure of atoms and of the radiation from them.") The elder Bohr, as a young graduate student in 1905, had written a prize-winning paper on the vibration of liquid drops of water. Seventy years later his son is being honored for work growing out of the liquid-drop picture.

The prize of $143 000, to be shared equally by Bohr, Mottelson and Rainwater, is to be awarded on 10 December in Stockholm. Bohr is director of the Niels Bohr Institute. Mottelson is a professor at NORDITA, the Nordic Institute for Theoretical Nuclear Physics, which shares quarters with the Bohr Institute in Copenhagen. Rainwater is professor of physics at Columbia University.

The liquid-drop picture of Niels Bohr, which had been subsequently elaborated by many workers, was very much in vogue in the 1940's. Then in 1949 Maria Goeppert Mayer, and independently J. Hans D. Jensen (collaborating with O. Haxel and H. E. Suess), introduced the shell model. The theory assumed that the nucleons move almost independently of each other under the influence of a common potential. (Mayer and Jensen shared the 1963 Nobel Prize for this work.)

But there were flaws in the shell-model picture for nuclei with quadrupole moments, particularly in the rare-earth region. The theory assumed a spherically symmetric nucleus, even when an odd nucleon was present; its predictions for the quadrupole mo-

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RAINWATER

White House science adviser: Teague bill progresses

Imminent revival of the post of White House science adviser appears likely as both House and Senate consider legislation that would reestablish an apparatus for science and technology in the Executive Office. Backed by the President, the "National Science and Technology Policy Act of 1975" bill unanimously reported out of Congressman Olin Teague's House Committee on Science and Technology restores the office of science adviser, articulates national policy goals for science, and creates a committee to examine further the relation between the federal government and scientific research. The bill passed in the House early in November with relatively minor amendments.

The House committee's bill calls on the President to appoint, subject to Senate approval, a Director for the proposed Office of Science and Technology Policy; the holder of this office would in fact be the new White House science adviser. His duties, outlined in the bill, include consulting with the President on those areas of national concern involving scientific and technical considerations, evaluating the quality of existing governmental efforts, developing criteria for the determination of scientific and technical research activities meriting federal support, and identifying those emerging regions where science can be employed effectively for future needs. With its specific mention of national security as an area in which the director is to advise the President—others are the economy, health, foreign relations, the environment, and technological recovery and use of resources—the bill resuscitates the science adviser's role in matters of military technology, excluded from his advisory functions in the reorganization plan that eliminated the former Office of Science and Technology in July 1973.

Prior to the disbanding of OST, six full-time White House science advisers served the Executive in the course of the Eisenhower, Kennedy, Johnson and guideway or equipment. For example, the railroads, although largely funded by industry, received large Federal subsidies in land for their tracks. Although automobile research is not subsidized, the government has provided major expenditures on highways. In aviation, the Federal government sponsored research on the vehicles themselves and on the guideways for those vehicles.

The Department of Transportation, formed in 1967, spent $200 million on R&D in FY 1970 and this fiscal year has an R&D budget of $400 million. Goodson feels there are basically very few problems with our transportation system today.

However, he says that "basic research in mobility initiatives has really suffered," with the killing of the SST, the decrease to zero for funding of the magnetically levitated vehicle, and the zero growth of the personalized rapid transit, small, automated vehicle for urban transportation.

By the year 2010, Goodson feels, we will either have a new technology in transportation, or we'll all be walking. The primary need in research will be in materials—to lighten motor vehicles while making them safer, to produce high-temperature propulsion, and to design energy-storage systems at low cost and high volume.

Harry Kimble (University of Rochester) and Don Page (Cal Tech) presented student views of industrial careers (see January 1976 issue of PHYSICS TODAY). At the same session Robert March (University of Wisconsin) was presented the AIP–US Steel Foundation Science-Writing Award by AIP director H. William Koch (PHYSICS TODAY, September, page 79). The speakers at a session on "Frontiers in Physics" were Keith Brueckner (University of California, San Diego), who discussed laser-induced fusion and Mortimer Mendelsohn (Lawrence Livermore Laboratory), who described biological cell parameter analysis.

Discussion groups met to consider questions of science and public policy. These groups were led by J. A. Krumhansl (Cornell University), Ellis Mottur (Office of Technology Assessment), J. Ross Macdonald (University of North Carolina, Milan Fiske (General Electric) and Franklin Huddle (Congressional Research Service). —GBL

Nobel prize

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ments were far lower than those being observed experimentally. During a colloquium at Columbia in 1949, Charles Townes described the discrepancy between theory and experiment (reported in a paper by him, Henry Foley and William Low). In the audience was Rainwater, who was struck by an explanation for producing a collective nuclear distortion.

As Rainwater explained to us, it seemed obvious to him that the shell model implied that the nucleus would take on the observed spheroidal shape if one did not insist on using the formalism implying a spherical shape. In the liquid-drop approach to the semi-empirical binding-energy formula, there was a surface term reflecting the smaller binding of surface nucleons, similar to surface tension for a liquid drop. For constant volume, the energy increased as the square of the distortion away from spherical shape, with the decrease in Coulomb energy helping to counteract the effect of the slow surface increase. This behavior had been understood before 1940.

The problem, he went on, was to discover a "forcing effect," in which the energy decreased linearly with the distortion so the equilibrium balance minimum energy would occur for a spheroidal shape. One nucleon starting a high angular momentum (l) orbit shell beyond a closed shell would have an equatorial orbit with kinetic energy varying inversely as the square of its orbit radius. Following the ideas of Bohr and John Wheeler, Rainwater realized that if the nuclear volume stays fixed but allows the equator to bulge towards disc shape (oblate spheroid), a 10% increase in equator radius yields a 21% decrease in the kinetic energy of the odd particle, thus providing the required linear "forcing term" in the energy. Because the entire nucleus distorts, a negative quadrupole moment results, which is amplified by the contribution of the odd nucleon, which can even be a neutron.

For a closed shell of high-l nucleons, Rainwater said, the orbits having large inclination with the equator give opposite sign contributions, and the net linear term averages to zero. For a closed shell minus one high-l nucleon, if the "hole" is for an equatorial orbit, a prolate spheroidal shape (cigar shape) is favored. If, in gradually emptying the shell, orbits closest to equatorial are removed first, the linear term and positive quadrupole distortion increases steadily until the shell is about half emptied, after which it decreases and, at some stage, shifts to favoring the opposite shape (as observed). A few months later Rainwater produced a detailed paper including a quantum mechanical treatment, and it was published in the summer of 1950.

That academic year 1949–50, Rainwater was sharing an office at Columbia—Room 910 at Pupin—with Aage Bohr, who was visiting for the year. The two men often discussed Rainwater's picture, which described the static behavior of the nucleus. Bohr was particularly interested in the dynamic aspects involving vibration and rotation of the bulge. In 1950 Bohr published the first of a series of papers developing this picture, continuing this work after his return to Copenhagen.

In the 1950 period another problem with the shell model had developed—it predicted much longer lifetimes for gamma decay than were being observed. Bohr joined forces with Mottelson to explain the gamma decays on the same basis as the quadrupole moments, namely that the excited state was the quantum analog of a classical oscillation of the nuclear shape as a whole; on that basis all particles in the nucleus would participate.

In 1953 Bohr and Mottelson published the first of a series of papers on the collective model; in their picture both collective and individual particle motions play a role. In the opening section of their paper, they indicate the direction that their subsequent work took: "One is thus led to describe the nucleus as a shell structure capable of performing oscillations in shape and size." That is, Bohr and Mottelson were striving to unify the shell-model and liquid-drop pictures of the nucleus. In the shell model the particles move more or less independently in a field of force that can be characterized as a container with fixed size and shape. In the new picture the container acts like an elastic bag, in which the motion of the nucleons inside determine the size and shape of the bag.

The early picture of Bohr and Mottelson was of nucleons behaving like a fluid inside a rotating football-shaped membrane. They quantized a deformed liquid drop to calculate rotational spectra.

In 1954 David Inglis (then at Argonne National Laboratory) introduced the so-called "cranking model." He argued that one could think of a football-shaped boundary rotating at a steady rate, as if it had a crank on it that was being turned steadily by an outside torque. By calculating the response of the system to the torque, Inglis could obtain the moment of inertia. If the system rotated as a rigid body, the moment of inertia would be high; if it acted as a fluid, the moment of inertia would be low. Actual values were in the middle.

Bohr and Mottelson extended the cranking-model method, going beyond Inglis's calculations for mostly closed-shell nuclei, applying it to nuclei with more nucleons beyond closed shells and introducing the interaction between nucleons. Meanwhile Felix Villars (MIT) was also extending the cranking model. Sven-Gösta Nilsson (then a doctoral student in Copenhagen) calculated the energy levels of nucleons in nonspherical containers, predicting how they would be deformed.

In 1957 John Bardeen, Leon Cooper and J. Robert Schrieffer (all then at the University of Illinois) developed the microscopic theory of superconductivity (for which they shared the Nobel Prize in 1972), in which they introduced the concept of pairing. Bohr, Mottelson and David Pines (who was visiting Copenhagen) applied these pairing ideas to finite nuclei, hoping to explain the energy gap observed in the intrinsic excitation spectrum of nuclei. S. T. Beylaev (also a visitor to Copenhagen) pursued this idea so that subsequent workers were able to calculate nuclear moments of inertia that agreed well with experiment. Beylaev's work was taken up by Leonard Kisslinger and Raymond Sorensen (then visiting Copenhagen), and by many others.

About 1964 Bohr and Mottelson developed the concept of the so-called "pairing vibrations," pointing out that there would be additional regularities in the spectra, not only within a single nucleus, but between families of nuclei, which differed in mass by two units.

Since the early 1950's Bohr and Mottelson and the Institute in Copenhagen have had a profound effect on nuclear physics. More than most theorists, they insist that the data must be examined and made sense of. They were very much involved with the experimenters.

One of these experimenters, Rainwater, was quite surprised that he had won the Nobel Prize for theoretical work. For the last 30 years or so, he has considered himself an experimental physicist. In fact, when he first received the traditional early-morning call on 17 October, Rainwater thought he was being honored for an experiment done in 1953 with Val Fitch on x rays from muonic atoms.

Biography. Rainwater, after graduating from Cal Tech in 1939, became a graduate student at Columbia, but during the war years he worked on the Manhattan Project under J. R. Dunning. In 1946 he got his PhD from Columbia, where he has been ever since. In 1952 he became a professor there; during 1951–54 and from 1957 to 1961 he was director of the Nevis Cyclotron Laboratory where he has spent most of his time since 1965 supervising the conversion of its synchrocyclotron to a meson factory.

Bohr studied at the University of Copenhagen, receiving his PhD in 1954. He became a research fellow at the Institute of Theoretical Physics (now the Bohr Institute) there in 1946 and became its director in 1963, when his father died. He was named professor of physics at the University of Copenhagen in 1956. In 1944–45 Niels and Aage Bohr worked on the Manhattan Project at Los Alamos Scientific Laboratory.

Mottelson, after graduating from Purdue University in 1947, earned a PhD at Harvard University in 1950. He then did a postdoc at the Bohr Institute. In 1953 he went to CERN, spending the next four years there. Since then he has been a professor at NORDITA, except for a year visiting at the University of California, Berkeley, in 1959. He became a Danish citizen in 1973. —GBL

the physics community

AIP film on hemoglobin shown on public television

Linus Pauling of Stanford University (see cover of this issue) discusses his investigations into the structure and function of hemoglobin in "Life and the Structure of Hemoglobin," a 30-minute film produced for the American Institute of Physics by PBS station KCET, Los Angeles. The project was funded by a grant to AIP from the National Science Foundation.

The film was transmitted to 256 PBS stations for its first national telecast, and PBS estimates that 80% of its affiliated stations broadcast the film on 1 October.

AIP is now distributing the film to schools and colleges through Oxford Films, a subsidiary of Paramount Pictures Corp, Hollywood, California. Persons interested in buying or renting the film (also available in videotape) should write to Gerald Present, American Institute of Physics, 335 East 45th Street, New York, N.Y. 10017.

The film focuses upon the efforts of physical scientists to understand the relationship between the structure of this complex protein molecule and the way in which it binds, transports and releases oxygen. Various research methods are discussed, including x-ray crystallography, nuclear magnetic resonance, laser spectroscopy and computer animation. Other scientists appearing in the film are Max F. Perutz (Cambridge University), Robert G. Shulman (Bell Laboratories), Robert Langridge (Princeton University) and John Hopfield (Princeton University), who serves as narrator. The film was written and directed by Bert Shapiro. It won a Gold Medal at the 18th International Film and TV Festival of New York on 7 November.

Hans Bethe retires. Shown at the reception climaxing a day-long program in his honor at Cornell University, where Bethe has been a professor of theoretical physics for 40 years. The program featured invited papers on nuclear physics, energy resources and astrophysics, reflecting the remarkably broad range of Bethe's interests in theoretical physics. Bethe was awarded the Nobel Prize for physics in 1967 for his work published in 1938 on the nuclear reactions underlying the energy production of stars. Framed picture at left depicts a bust that will be displayed on the top floor of the Cornell physics building where two rooms have been renamed in his honor—the "Bethe Auditorium" and the "Bethe Seminar Room." One speaker, Gerald Brown, paid tribute to Bethe as "a steamroller of logic, crushing irrational, emotional argumentation of those who would misuse science to their own ends."