Niels Bohr as fund raiser

Bohr's dealings with the Rockefeller Foundation were decisive in bringing about the successful reorientation of his institute from atomic to nuclear physics in the 1930s.

Finn Aaserud

Nuclear physics came of age as a discipline in the 1930s. In 1932, the "miraculous year" of nuclear physics, physicists discovered two new particles, the neutron and the positron, developed revolutionary particle-accelerator equipment and split nuclei for the first time by manmade machines.[1] The study of the nucleus soon developed into an independent field, becoming the central area of research in theoretical physics. During the mid-1930s, Niels Bohr's Institute for Theoretical Physics at the University of Copenhagen experienced a successful transition to the new field of investigation, consolidating its position as an international Mecca for theoretical physics research. In early 1936 Bohr proposed his revolutionary compound-nucleus model, and in late 1938 the Bohr institute's cyclotron, a major device for provoking nuclear reactions, was the first such apparatus to go into operation in Europe. Since then, Bohr's institute has been an international leader in theoretical nuclear physics research.

What was the background of Bohr's successful redirection of his institute from atomic quantum theory to nuclear physics? In this article I argue that Bohr's activities as an institute director in dealing with changes in funding conditions for international basic science, occasioned in particular by new policies of the Rockefeller Foundation, played a crucial role in inducing the change. The discussion sheds light on the little-investigated relationship between scientific and administrative matters at Bohr's institute. It brings forth an important aspect of Bohr's activities that has commonly been ignored in favor of his unique abilities as a scientist and as a teacher for several generations of the most eminent theoretical physicists.

Finn Aaserud is associate historian at the American Institute of Physics, Center for History of Physics, in New York. He is the author of a book tentatively titled *Scientist and Administrator: Niels Bohr and his Institute in the 1930s*, to be co-published in 1986 by the Institute of Physics, Bristol, England, and the American Institute of Physics, New York.

The 'Copenhagen spirit,' 1921–33

In their reminiscences, physicists who worked at Bohr's institute between the world wars emphasize the unique "Copenhagen spirit" of scientific investigation.[2] They remember this spirit as, first, an unlimited freedom, in a completely informal atmosphere, to pursue whatever problems in theoretical physics that they considered most urgent. The second aspect of the Copenhagen spirit, as they recall it, was that this pursuit took the form of intense discussions between Bohr, the acknowledged master, and the most promising, yet young and unestablished, physics students visiting his institute from several countries. Dependent upon a human sounding board on whom to try out his ideas, Bohr encouraged some visitors at his institute to become his "helpers"—that is, to take part in his own thinking process. The Copenhagen spirit thus comprised complete freedom of research pursued within a division of scientific labor between Bohr and the cream of international theoretical physics students.

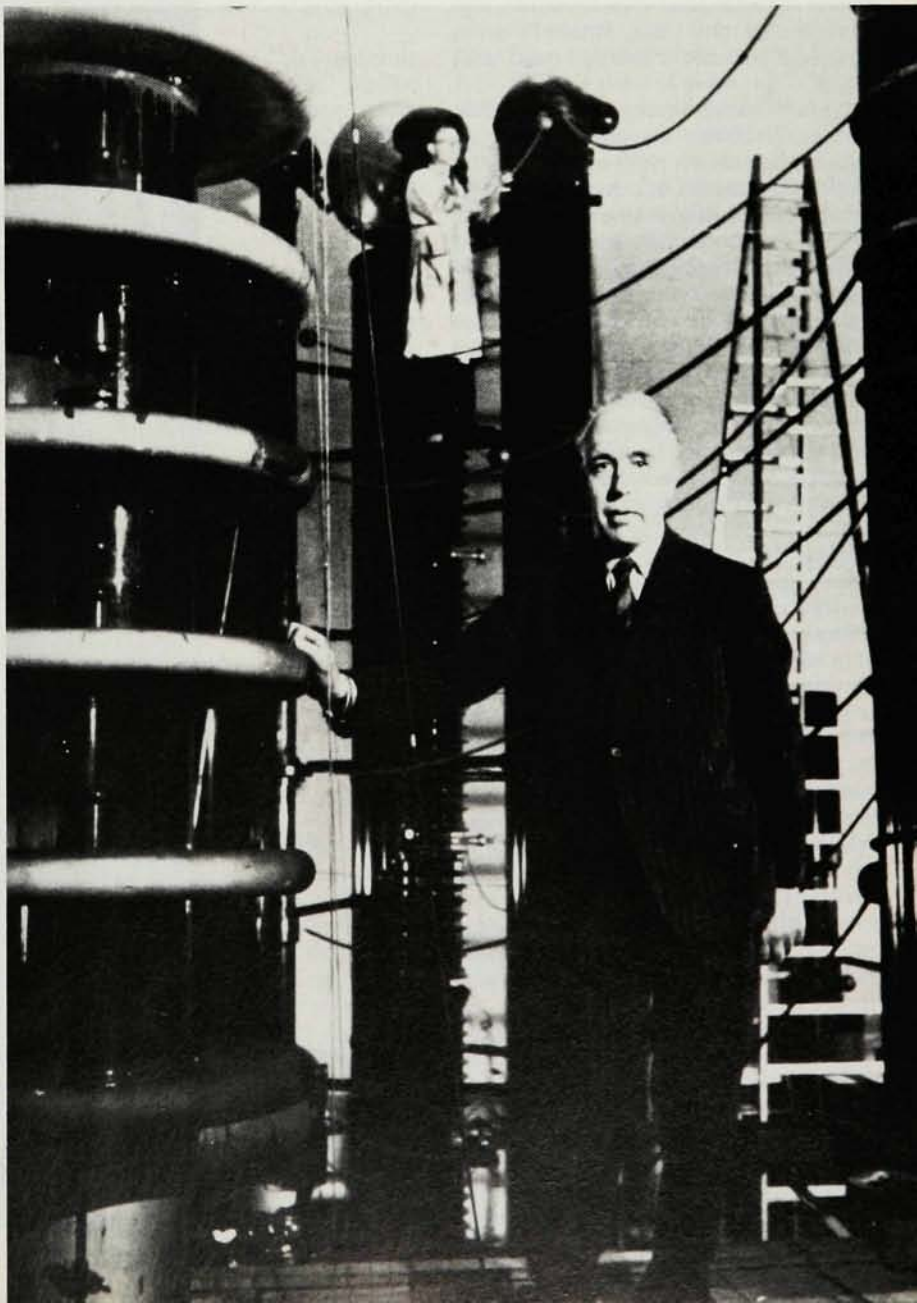
In the physicists' accounts, the freedom reflected in the Copenhagen spirit is implicitly contrasted with the constrictions of administrative work. Yet, although rarely noted by the reminiscing physicists, Bohr was involved from the outset in matters of administration; in particular he worked hard for several years to secure the funds necessary to establish his institute in 1921. In fact, Bohr's justification for creating an institute for theoretical physics—to establish a union between physical theory and experiment—made it particularly necessary for him to involve himself in questions of funding, and he made a substantial effort to formulate elaborate—and successful—funding proposals toward this end. Bohr thus established what amounted to a research program for his institute: theoretical and experimental work on the manifestations of electrons orbiting the atomic nucleus.[3]

Bohr's substantial prestige as a scientist and institute director allowed him to avoid difficulties in obtaining support, first from such Danish agencies as the Carlsberg and Rask–Ørsted Foundations, and later from an American agency, the Rockefeller-funded International Education Board.

The IEB, conceived of and led by Wickliffe Rose, a long-time Rockefeller philanthropy administrator, was explicitly devoted to "making the peaks higher" in contemporary international, particularly European, basic science research. Pursuing an elitist "best science" policy of exposing the most promising postdoctoral students to the very best institutions of research, it considered general quality and prestige, rather than specific projects or research goals, as criteria for funding.[4] Bohr's application for an expansion of his institute was accepted even before Rose set out in 1923 on an extensive tour to survey the needs of European basic science. This grant constituted the IEB's first support to any physics

0031-9228 / 85 / 1000 38- 09 / $01.00

Niels Bohr with the Cockcroft–Walton high-voltage equipment at his institute, in the late 1930s. This was the first large-scale nuclear physics apparatus to be installed at the institute. (Niels Bohr Institute photograph, courtesy AIP Niels Bohr Library.)



institution. In obtaining this support, Bohr was able to confirm the extent and importance of his prestige, as well as to consolidate the union between theory and experiment he had advocated from the institute's establishment. Furthermore, the IEB's emphasis on quality and prestige allowed the freedom—contained in the Copenhagen spirit—to take up any question without regard for immediate utility.

Although support for building and equipment made up the largest part of the IEB's budget, its substantial fellowship program was the backbone and major justification for all of its basic science funding. This program supplied Bohr with eminent younger collaborators such as Werner Heisenberg and Pascual Jordan from Germany, Samuel Goudsmit from Holland and George Gamow from the Soviet Union. Together with the Rask–Ørsted Foundation, which offered a similar fellowship program, the IEB provided the economic means for the division of scientific labor between Bohr, the international leader of theoretical physics, and his young and eminent, but unestablished, colleagues. Arriving in Copenhagen to put the finishing touches on their scientific education, the visiting physicists were strongly motivated to discuss their research problems with the acknowledged master, as well as to work as Bohr's helpers. The division of labor between Bohr and his younger collaborators, then, was reinforced by Bohr's active exploitation of the existing funding opportunities. Bohr's involvement in physics and administration were not in conflict, but reinforced one another.

The spirit in action. The lack of emphasis in physicists' recollections on Bohr's administrative work is now easier to

Wickliffe Rose. Rose led the Rockefeller-funded International Education Board from 1923 to 1927. (Courtesy Rockefeller Archive Center, Pocantico Hills, New York.)

understand. Destined to stay in Copenhagen for a limited period of one to two years, without any prospect for advancement in Danish science, the young visitors at Bohr's institute saw no reason—and were not encouraged—to involve themselves in matters of administration. The physicists' concentration, in their recollections, on disinterested scientific discussion hence reflects their own situation and concerns at the time, rather than a complete portrait of Bohr's actual activities.

Nevertheless, during the late 1920s and early 1930s, the day-to-day theoretical discussion represented by the Copenhagen spirit was crucial in determining the development of science at Bohr's institute. In his address of appreciation to the Danish Academy of Sciences and Letters in late 1931 upon being chosen as the resident of the honorary Carlsberg Mansion, Bohr went as far as to express regret that living on the institute's premises had involved him in theoretical discussions at the expense of planning and following experimental research. He looked forward to being able to make plans for his institute from a distance. Yet, during the following couple of years Bohr continued to concern himself mainly with fundamental questions in quantum physics. Of these, the extension of quantum theory to the relativistic domain was considered particularly urgent. Many physicists expressed frustration about the meager progress in this direction. Bohr, however, pursued the problem with characteristic zeal and optimism. Thus, while he followed closely the events of the miraculous year, 1932, of nuclear physics, he scrutinized their general implications for his study of quantum theory, without seeking to change the long-established union between theory and experiment at his institute.

Bohr's rising interest in biological questions, first expressed publicly in 1929, was also oriented toward theory and discussion. His interest in biology came out of his concern with the epistemological implications of quantum mechanics; he pursued the subject in discussions with fellow theoretical

Warren Weaver. Weaver was the Rockefeller Foundation's natural sciences director from 1932 to 1955. (Courtesy Rockefeller Archive Center.)

physicists, with no intention of bearing upon the experimental work at his institute. Hence, in spite of Bohr's original emphasis on a union between theory and experiment, from the second half of the 1920s through 1933, the crucial element in forming the concerns and activities at his institute, even outside theoretical physics, was the Copenhagen spirit, which emphasized open theoretical discussion rather than the initiation of experimental projects. By early 1934 the concerted scientific reorientation toward nuclear physics had yet to take place.

Help to the refugees, 1933–1934

In 1933 the Rockefeller Foundation instituted an emergency program for the academic refugees from Nazi Germany. Contrary to traditional funding policy for international basic science personnel, this program centered on established scientists, and thus did not serve to sustain the division of scientific labor between Bohr and his younger helpers. Nevertheless, Bohr did not hesitate to appeal to the new program to further research at his institute. The resulting departure from the Copenhagen spirit would eventually hasten the transition to nuclear physics.

Bohr had been exposed immediately to the problem of the physicist refugees, most of them Jewish, after Adolf Hitler's accession to power in Germany in January 1933. He was continually informed about developments by his Danish assistant Ebbe Rasmussen, who just before Hitler's takeover had gone to Berlin on a one-year fellowship from the Rockefeller Foundation. Early on, Rasmussen urged Bohr to use his influence to help the young and less established refugee physicists, who were hit particularly hard. During the following months Bohr also solicited reports on developments from German physicist colleagues.

In October he joined the executive board of the newly established Danish Committee for the Support of Refugee Intellectual Workers, which like other European national refugee committees concentrated on helping the less well-known refugees. Through this committee, as well as through the traditional fellowship programs, Bohr was able to create a temporary haven for young physicist refugees at his institute. Consequently, Bohr's personal priorities in handling the refugee problem, as expressed before his exposure to the Rockefeller Foundation's emergency program, did not affect the division of scientific labor at his institute, where the Copenhagen spirit continued to serve as the main inspiration for physics research.

In early May 1933, at the beginning of an extended visit to the United States, Bohr urged Max Mason, president of the Rockefeller Foundation, which in the meantime had taken over the IEB's fellowship program for young natural scientists, to abolish the requirement that fellowship recipients should have a position to return to. Without such action, Bohr reasoned, the fellowship program would not provide sufficiently effective help for the hardest-hit refugees. It was in the course of Bohr's American visit, however, that the Rockefeller Foundation decided upon its emergency program toward the academic refugees.

The new program sought to establish positions for the most established and renowned of the academic refugees, with emphasis "on the preservation of scholarship rather than on personal relief for scholars."[5] The American Emergency Committee in Aid of Displaced German Scholars, established at about the same time and collaborating closely with the Rockefeller Foundation, explicitly excluded aid "to younger German scholars of outstanding promise."[6]

In spite of Bohr's and the Rockefeller Foundation's different approaches to the refugee problem, Bohr did not hesitate to make the best of the foundation's new program for his institute and for two of his closest physicist colleagues. Before his departure from the United States, he had already met with the Rockefeller Foundation's natural sciences director, Warren Weaver, for this purpose. Bohr's subsequent formal application for salaries for James Franck and George Hevesy to work at his institute for three years was approved in January 1934. The prominence of these two scientists in the international physics community, as well as their different personalities, would prove crucial for the subsequent developments at Bohr's institute.

Franck and Hevesy. Franck was a prominent experimental physicist who had quit his prestigious professorship at Göttingen University soon after Hitler's accession to power. Although Jewish, Franck was not affected by the racial laws, owing to his engagement in front-line combat during the First World War. Nevertheless, he was unable to accept the regime's actions against his Jewish colleagues.[7]

After their first meeting in 1920, Bohr and Franck had developed a close personal and scientific relationship. Franck, who was three years older than Bohr, was a strong admirer of Bohr's theoretical work and devoted a substantial part of the following years to the experimental verification of Bohr's theories. In the process he studied increasingly larger and more complex physical systems. Having started with individual atoms, Franck was investigating processes on the molecular level by the time he moved to Copenhagen.

Hevesy, although an experimenter like Franck, represented a significantly different approach to scientific research. Having a background in physical chemistry, he tended to apply the most advanced techniques of modern physics research not to answering urgent questions of theoretical physics, but rather to obtaining more precise information in a variety of fields. Thus he employed his knowledge of radioactive isotopes—acquired during an extended apprenticeship at Ernest Rutherford's laboratory in Manchester from 1911 to 1913—to developing the radioactive indicator technique, which enabled him to identify and measure minute quantities of elements embedded in other material.

Bohr and Hevesy had developed a close friendship based on mutual admiration during their shared period in Manchester in 1912, shortly after Bohr had completed his doctoral work in Copenhagen. Hevesy, less than three months older than Bohr, was more extroverted, standing up publicly for

Groundbreaking. Niels Bohr takes a symbolic step toward the expansion of his institute, *circa* 1935. (Courtesy Niels Bohr Institute.)

Bohr's views at a time when they were not generally accepted. Whereas Bohr admired Hevesy's more practical bent, Hevesy for his part considered Bohr's theoretical intuition unique.

Nuclear work begins, 1934

In the difficult period that Hevesy's home country, Hungary, underwent following the First World War, Bohr invited his friend to work at his newly established institute. Although Hevesy provided an important verification of Bohr's atomic theory of the periodic system by codiscovering the element hafnium in 1922, this event was only his first step toward developing x-ray techniques for the study of minerals. In the 1920s Hevesy devoted most of his time to designing and applying such x-ray techniques, having momentarily exhausted the radioactive indicator technique, owing to the small number of naturally occurring radioactive isotopes.

As a more marginal effort in Copenhagen, Hevesy also sought to apply his radioactive indicator technique to investigating the exchange of some elements in living plants and animals. There is no indication that Bohr at the time expressed interest in this work, which Hevesy pursued in collaboration with other prominent Danish scientists and institutions. The work shows Hevesy's independence and his different approach to scientific research.

After six years in Copenhagen Hevesy accepted a call to become professor and director of the Institute for Physical Chemistry at Freiburg University in Germany, where he intensified the research efforts he had begun in Copenhagen. In the summer of 1933 he decided to retire from this position owing to the situation provoked by the Nazi takeover in Germany. He kept postponing his departure, however, and did not move permanently to Copenhagen until September 1934.[8]

Before the arrivals of Bohr's two prominent friends, neither Bohr, Franck nor Hevesy had specific plans for what kind of research the newcomers would pursue in Copenhagen. Upon his arrival in early April 1934, after a semester in the United States, Franck set out to study the fluorescence of green leaves—a natural extension of his previous researches, which required a minimum of equipment. However, Bohr saw quickly that the need of the two established experimenters—former professors and institute directors—for their own equipment, assistants and research projects could be used as an opportunity to follow up the experimental investigations of the atomic nucleus begun in March by Enrico Fermi and his collaborators in Rome.

After the discovery by Irène and Frédéric Joliot-Curie in Paris that some elements could be made "artificially" radioactive through bombardment with protons, the Rome physicists had set out to bombard systematically all chemical elements with neutrons. Because neutrons, unlike protons, would not be repelled electrically when approaching the positively charged nucleus, nuclear reactions could be obtained at smaller energies, and hence at lower cost.

The new experimental developments consolidated the successes in nuclear physics during the miraculous year of 1932. They distinguished themselves from the latter events, however, in having an immediate effect on experimental work at Bohr's institute. Although such experiments had never before been reported from Copenhagen, and despite Franck's lack of experience in nuclear physics, Bohr wrote Heisenberg in the second half of April 1934 that Franck was directing experimental investigations at the institute along the same lines as the work on radioactive phenomena in Paris and Rome. Bohr subsequently arranged for Otto Robert Frisch, a young refugee physicist and nuclear experimenter, to come to the institute as Franck's assistant. While absent on a trip to the Soviet Union in early summer, Bohr induced Franck and Hevesy to correspond about the acquisition of Cockcroft–Walton high-voltage equipment for nuclear investigations.

By the end of the year only one publication had come out of the Copenhagen neutron bombardment program. During this period Franck complained in his correspondence about his lack of expertise, and about the appearance in *Nature* of his own findings—arrived at independently by other physicists—before he had had a chance to write them down for publication himself. Nevertheless, in December Bohr reported in a letter to his colleague Ralph Fowler in Cambridge that "the whole laboratory is busily occupied with research on nuclear physics under the effective guidance of Franck and Hevesy."[9]

In short, during 1934 Bohr's concern for physics in relation to his institute changed from a theoretical interest in the fundamental problems of quantum physics to an effort to introduce new experimental research on the atomic nucleus. This change cannot be understood in terms of developments in

Bohr's institute after its expansion in the 1930s. (Courtesy Niels Bohr Institute.)

physics alone. Bohr had followed closely the experimental study of the nucleus from the outset. However, as long as the funding policy for international basic science did not change, research pursued in the Copenhagen spirit did not provoke a change in the institute's research effort. Although Bohr showed immediate enthusiasm for the developments in nuclear physics in 1932, a concerted change in the emphasis of the research at his institute was triggered only by his willingness and ability to take advantage of the Rockefeller Foundation's new approach to the international funding of elite scientists represented by the emergency program for the academic refugees.

Physics tools and biology, 1934–35

While the Rockefeller Foundation's emergency program toward the academic refugees worked against the Copenhagen spirit by bringing two renowned physicists to Bohr's institute, the same foundation's substantially more ambitious "experimental biology" funding program challenged the precept of undirected "best science" itself. This program sought specifically to place biological research on what the foundation viewed as the more solid basis of mathematics, physics and chemistry. The new program was an even more profound counterpoint to the previous funding policy, still practiced by other agencies, that had sustained the Copenhagen spirit. Nevertheless, Bohr quickly took advantage of the new program to continue the transition to nuclear physics at his institute.

At the end of the 1920s the Rockefeller philanthropists had begun a far-reaching reconsideration of their basic science policy. The educationally motivated best-science policy of Rose's International Education Board came to be seen as too broad, and hence too scattered and expensive. When it was decided, in 1927, that the Rockefeller Foundation would take over the IEB's responsibilities for science funding, Rose chose to leave Rockefeller philanthropy for good. It took time, however, for the foundation's new natural sciences division to decide upon a well-defined alternative policy. Only when the physicist Weaver was appointed as its director in late 1931 did a reorientation of the foundation's "major program" of science funding begin. The new program was soon to emerge as "experimental biology."[10]

In the course of intense internal meeting activity and committee work, especially during 1933, the new funding policy crystallized. Instead of supporting individuals and institutions on the basis of their general prestige and quality, the Rockefeller Foundation decided to concentrate on "the application of experimental procedures to the study of the organization and reactions of living matter."[11] By encouraging work in biology using modern theoretical concepts and experimental techniques from mathematics, physics and chemistry, the foundation hoped to advance the putatively backward life sciences. Economic hardship induced the foundation during 1934 to increase the number of "project grants" at the expense of the previously more common general-purpose grants. Under Weaver's leadership the Rockefeller Foundation set out on an unprecedented attempt to guide international basic science in a preferred direction.

Even before the Rockefeller Foundation's new major program was defined with any rigor, Weaver was eager to add prestige to his division by attracting the renowned Bohr to his funding program. Thus, although no biologically oriented work had ever been done at Bohr's institute, Weaver made the institute his first stop in Copenhagen during a grand tour in the spring of 1932 of "essentially all of the university centers of western and south-western Europe."[12]

Meeting with Weaver in New York a year later, Bohr suggested the possibility of bringing together at his institute one, two or three "able and thoroughly trained young men in mathematics, physics or chemistry, who under B[ohr]'s direction turn their attention to some quantitative phase of important biological problems."[13] In April 1934, when Wilbur Earle Tisdale and David Patrick O'Brien from the Rockefeller Foundation's Paris office visited Copenhagen to discuss specific research proposals, Bohr was equally vague about the kind of biological activity he would like to see funded. His statements thus reflected his own philosophical and general interest in biology, which was in conformity with the Copenhagen spirit of open and disinterested scientific discussion. Notwithstanding their eagerness to find a way to support Bohr, the Rockefeller Foundation's officers judged that Bohr was too far from suggesting, as required by the major program, a specific experimental project. Hence, Bohr was not at the moment considered a candidate for support.

By the time of Tisdale's next visit to Copenhagen in October, Bohr's concern for general theoretical questions in

James Franck (center) and George Hevesy (right) with Niels Bohr, on the porch of Bohr's institute in the 1930s. (Courtesy AIP Niels Bohr Library, Margrethe Bohr collection.)

physics was being replaced by his enthusiasm for Franck and Hevesy's work in experimental nuclear physics. Tisdale found that Bohr's attitute toward experimental biology had also changed dramatically. While previously "Bohr's interests [in biology] were mainly on the philosophical side," Tisdale noted[14] in his diary, "in recent months he has come to feel that it may be possible to do more effective work at the present time in connection with definite problems." In effect, Bohr suggested that the possibility of producing radioactive isotopes artificially made Hevesy's radioactive indicator technique suitable for biological problems.

Bohr proposed that high-voltage equipment, of the kind Franck and Hevesy had previously corresponded about for other reasons, be installed at his institute for the production of biologically useful isotopes. He proposed further that August Krogh, a prominent Danish physiologist and Nobel laureate in medicine, join the project as a third person, to provide the required biological expertise. Obviously, Bohr had come to perceive the Rockefeller Foundation's experimental biology program as a possible means to acquire equipment for experimental nuclear physics research. At the same time he was able to define a research program for Hevesy in direct continuation of the latter's previous concern and work.

Applications approved. During the next few months Bohr conducted detailed negotiations with the Rockefeller Foundation, seeking to define a research project acceptable for funding. By December he had become more confident about the foundation's particular emphasis on his own scientific renown. Although he had previously stressed the importance of Krogh's biological expertise, Bohr now simply presented Hevesy's study of the elements' "fate in the body" as the central theme, noting for the first time an especially promising artificially induced radioactive isotope—phosphorus.

When Bohr, in late January 1935, applied for the first time in almost ten years to the Carlsberg Foundation for substantial new and expensive equipment, he argued that acceptance of the current application was a condition for continued support from the Rockefeller Foundation. He did not, however, mention that the support from the Rockefeller Foundation was for biology, not physics. Instead, he motivated his request for a fully equipped high-voltage laboratory by noting the general shift in emphasis in theoretical physics from an interest in the atom's orbiting electrons to an interest in its nucleus. Unlike the Rockefeller Foundation, the Danish agency had not changed its funding policy, and Bohr may have judged that the new work in biology was irrelevant from the point of view of the Carlsberg Foundation. In any case, Bohr's application was approved in early February on the condition that running expenses for the high-voltage laboratory be obtained from other sources.

Bohr referred to this condition toward the end of February, when he finally formulated an elaborate letter of application to the Rockefeller Foundation. In this application Bohr did not even mention Krogh's name. Instead, Bohr projected[15] in general terms the "cooperation between [his institute] and Danish biological institutions to utilize the new possibilities for the investigation of fundamental problems in biology opened by the recent advances in atomic physics." Bohr was clearly becoming increasingly aware of the Rockefeller Foundation's emphasis, within the framework of constructing a physics-based biology, on his own prestige rather than on the specific proposals of biologists. Yet, as the application did not formulate a well-defined biological project, Hevesy, when delivering it personally in Paris, found it pertinent to assure[16] Tisdale "that this project, involving as it does so much of physics, is completely oriented towards bio-physical problems and is in no wise an attempt on Bohr's part to obtain equipment to permit him to in any wise compete with the Rutherfords, the Lawrences, and others who are working in the field of pure physics."

Although the changes in the Copenhagen experimental-biology proposals from October 1934 to February 1935 did arouse suspicion among some Rockefeller Foundation officers that the project was not sufficiently planned, or even that it might contain too little biology, the foundation granted support in April. As requested, the foundation provided funds for a cyclotron, as well as for assistants, equipment and running expenses for experimental biology for five years. In changing his attitude toward the Rockefeller Foundation's experimental-biology program, Bohr had not only introduced at his institute new research outside the domain of physics; he had also been able to obtain advanced equipment for experimental nuclear physics research.

Transition consolidated, 1935–39

The year 1935 brought a revolution in the economic situation of Bohr's institute. In addition to the support from the Carlsberg and Rockefeller

Foundations, the Thrige Foundation, established from the profits of the largest electrical firm in Denmark, provided the electromagnet for the institute's cyclotron. For Bohr's 50th birthday on 7 October, Hevesy masterminded what became known as the "radium gift"—funds for the acquisition of 600 milligrams of radium, contributed by some 16 Danish firms and foundations.

In this and following years Bohr also obtained support from agencies emphasizing medical and biological, rather than physical, research. Thus he applied to a Danish agency for funds to pursue "atomic-physical investigations as preparations for physiological experiments."[17] Moreover, he applied successfully to both the Carlsberg and Rockefeller Foundations for additional support for the cyclotron. Finally, in addition to obtaining increased running expenses from the Carlsberg Foundation, Bohr instigated collaboration in 1938 with the Danish Cancer Committee to build equipment for the treatment of cancer.

Bohr's appeals for support for biological research were not merely a tactic to secure the transition at his institute to nuclear physics. Although continuing to do work mostly on induced radioactivity during his first two years in Copenhagen, the prolific Hevesy collaborated with Krogh and published papers with two other prominent Danish scientists and institutions on the exchange of phosphorus in animals and plants. By 1937 Hevesy had turned all his energies toward applying his radioactive indicator technique to biological problems. In addition to expanding the collaboration with other scientists and institutions, Hevesy developed his own small group of younger collaborators at Bohr's institute. Although Hevesy and his collaborators employed the same experimental apparatus as the physicists, in doing biological experiments they worked on entirely different problems, and there was little communication between the two groups. While Hevesy quickly developed a reputation as the world's expert in his line of work, the visiting physicists do not remember him as participating in the kind of open discussion represented by the Copenhagen spirit. Not only the subject matter, but also the more project-oriented style of Hevesy's research differed substantially from the physicists' approach.

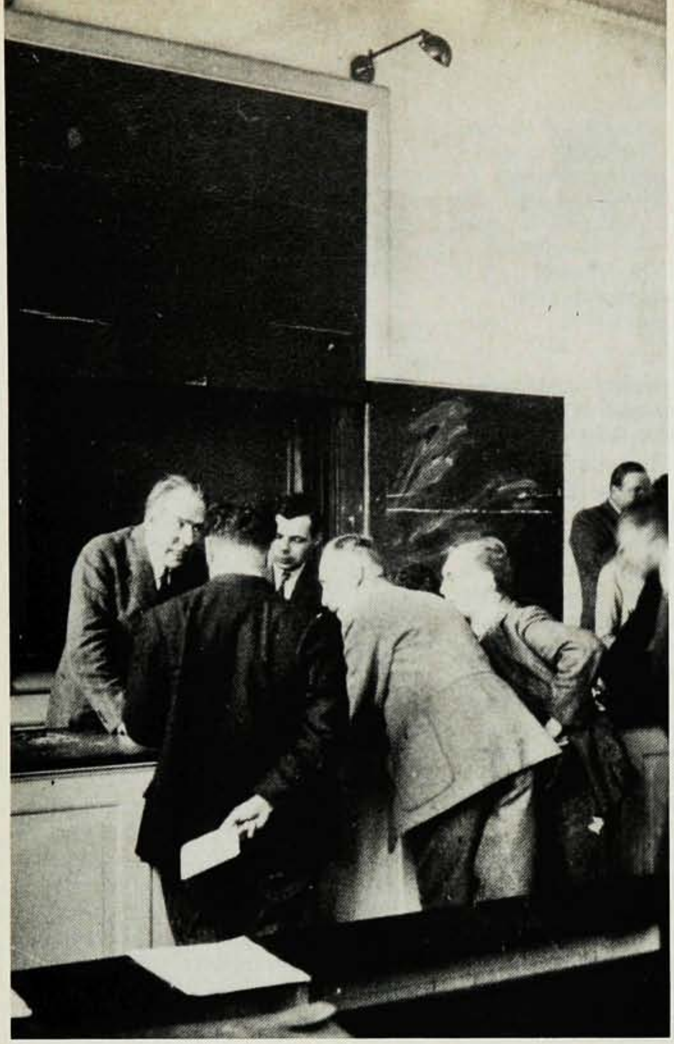
Thus, in the latter half of the 1930s the physics research at Bohr's institute continued to be pursued mainly through open and intense theoretical discussion. Bohr made this continuity possible by leaving it to Hevesy to take care of the Rockefeller Foundation's demand for a specific project. The work of the physicists dealt increasingly with problems relating to the atomic nucleus. In early 1936 Bohr presented his revolutionary "compound nucleus" model, and in the same year the majority of published papers from Bohr's institute was devoted for the first time to nuclear problems. This emphasis remains today.

Although Franck left Bohr's institute in mid-1935 to take up a position in the United States, Frisch, who had originally arrived to become Franck's assistant, stayed for almost five years and was crucial in carrying out the transition to nuclear physics.

The installation of the Cockcroft–Walton equipment supported by the Carlsberg Foundation was conceived and directed during the early stages by the German experimental physicist Arthur von Hippel, Franck's son-in-law. First, in the spring of 1938, it supplied x rays for cancer therapy, and then, around New Year 1939, it served as a particle accelerator for nuclear studies. The cyclotron was built by Lawrence Jackson Laslett, who was lent for the purpose from Ernest Orlando Lawrence's laboratory in Berkeley. It went into service in November 1938 as the first working cyclotron in Europe.

At about this time Frisch and his aunt Lise Meitner, who had just escaped Nazi Germany, were able to explain the process of nuclear fission on the basis of Bohr's conception of the nucleus. This explanation—occasioned by the experimental findings of Meitner's previous collaborators in Berlin, Otto Hahn and Fritz Strass-

Otto Robert Frisch. Bohr arranged for this young refugee physicist and nuclear experimenter to come to his institute as Franck's assistant. (Courtesy Niels Bohr Institute.)



The Copenhagen spirit in action. Bohr faces Wolfgang Pauli (back to camera), Lothar Wolfgang Nordheim, an unidentified man and Léon Rosenfeld. (Courtesy AIP Niels Bohr Library, Landé collection.)

mann—led to a concrete research program at Bohr's institute employing the new experimental equipment. Physicists used the high-voltage equipment, and subsequently the cyclotron, to study fission, with Bohr taking an active part in both the theoretical and experimental investigations. In 1939, on a visit to Princeton, he coauthored a seminal article on "The Mechanism of Nuclear Fission" with his younger collaborator John Archibald Wheeler. (See the articles on pages 48 and 66.) By this time the union between theory and experiment in physics at Bohr's institute had definitely become based upon nuclear physics, and the institute maintained its place as an international Mecca for theoretical physics research.

References

1. D. J. Kevles, Phys. Teach. **10**, 175 (1972); C. Weiner, PHYSICS TODAY, May 1972, p. 40; R. H. Stuewer, *Nuclear Physics in Retrospect: Proceedings of a Symposium on the 1930s*, Univ. Minnesota P., Minneapolis (1979).
2. The original meaning of the term referred to the conceptual approach to physics at Bohr's institute; see W. Heisenberg, *The Physical Principles of the Quantum Theory*, Dover, New York (1930), preface. The more recent meaning of the term can be obtained from numerous physicists' reminiscences, but see in particular L. Rosenfeld, *Niels Bohr: An Essay Dedicated to Him on His Sixtieth Birthday 1945*, North Holland, Amsterdam (1949); V. Weisskopf in *Physics in the Twentieth Century: Selected Essays*, MIT, Cambridge, (1972), p. 52. The concept is discussed at some length in P. Robertson, *The Early Years: The Niels Bohr Institute 1921–1930*, Akademisk Forlag, Copenhagen (1979), p. 152.
3. As a notable exception, P. Robertson, *The Early Years: The Niels Bohr Institute 1921–1930*, Akademisk Forlag, Copenhagen (1979) stresses the administrative aspect of Bohr's work at the institute.
4. G. W. Gray, *Education on an International Scale: A History of the International Education Board, 1923–38*, Harcourt Brace, New York, (1941); R. E. Kohler, Minerva **16**, 480 (1978).
5. "The problem of the refugee scholars," p. 3, typewritten, undated report, circa 1940, in the Rockefeller Foundation Archive (RFA), Pocantico Hills, New York, record group 1.1, series 717, box 1, folder 6 (1.1,717,1,6).
6. *Report of the Emergency Committee in Aid of Displaced German Scholars*, 1 January 1934, p. 11, pamphlet contained in RFA (1.1,717,1,1).
7. A. D. Beyerchen, *Scientists Under Hitler: Politics and the Physics Community in the Third Reich*, Yale U. P., New Haven (1977), p. 15.
8. For an apt description of Hevesy's personality, see H. Levi, *George de Hevesy*, Adam Hilger, Bristol (1985).
9. Letter from Bohr to Fowler, 12 December 1934, Bohr scientific correspondence, microfilm 19, section 2, deposited in the Niels Bohr Archive, Copenhagen, the AIP Niels Bohr Library, New York, and elsewhere.
10. R. E. Kohler, in *The Sciences in the American Context: New Perspectives*, N. Reingold, ed., Smithsonian Institution, Washington, D.C. (1979), p. 249; P. Abir-Am, Social Studies of Science **12**, 341 (1982).
11. "Report of the Committee of Appraisal and Plan," p. 58, in RFA (3,900,22,170).
12. W. Weaver, *Scene of Change: A Lifetime in American Science*, Scribners, New York (1970), p. 65.
13. Warren Weaver diary, 10 July 1933, RFA, record group 12.
14. Wilbur Tisdale diary, 29 October 1934, RFA, record group 12.
15. Letter from Bohr to Tisdale, 22 February 1935, RFA (1.1,713,4,47) (transcribed version), and Bohr general correspondence, special file, microfilm 6, section 1 (BGC-S 6,1), Niels Bohr Archive, Copenhagen (Bohr's carbon copy).
16. Letter from Tisdale to Weaver, 27 February 1935, RFA (1.1,713,4,47).
17. Letter from the Nordic Insulin Foundation to Bohr, 22 March 1934, BGC-S 3,4. □