reminiscences of

NIELS BOHR

By ***Felix Bloch***

THIS special occasion, I realize, calls for a special selection among the many remarkable instances which the name of Niels Bohr brings back to my mind. It seemed indicated, at first, that I should restrict my account to those reminiscences which bear directly upon specific topics in physics and to omit others of more general human interest. But as I thought more about this talk, I realized that such an omission would present a grossly distorted picture, and that an essential feature of Bohr's character would be lost if one tried to distinguish between the professional and the personal manifestations of his great personality.

I shall therefore not hesitate to tell you first about an encounter which took place on the staircase of the Institute in Copenhagen shortly after I arrived, in the fall of 1931, to spend some time there as an Oersted Fellow. I have to mention that I had met Bohr earlier and that my original feelings of awe by then had been melted away by his great warmth and his fine sense of humor. On that occasion he greeted me with the question: "Do you also belong to that gang?" It was fairly obvious that he referred to George Gamow, Max Delbrück, and their associates, who had just cleared the field, and whose practical jokes and otherwise frivolous behavior were rapidly becoming a legend all over Europe. Nevertheless, to be quite sure, I asked him whether he meant those people who took nothing seriously and did not respect anybody. Then Bohr smiled, and said in the most wonderful plural of majesty: "Oh, but we do not take their lack of respect seriously either." Of course, Bohr was quite right, and in this sense I could claim to be a full member of the famous gang.

Shortly afterwards my living quarters were established in two small rooms under the roof of the Institute, with a narrow staircase leading down to the library. As a more important geographical feature, Bohr had not yet moved to the fine residence on the grounds of the Carlsberg Brewery but at that time still lived with his family in the smaller house adjacent to the Institute. This proximity gave me the opportunity, during my stay in Copenhagen, for a close association with him for which I still envy myself.

My formal duties were, as far as I could ever find out, nil, and my contacts with Bohr were of the most informal nature imaginable. Although he was meticulously conscientious, the keeping of time schedules was just not his greatest strength, and I had to become used to discussions which, sometimes, extended over weeks and took place at intervals of random length and at random hours of day or night.

What was the content of these discussions? It sounds like a simple question which deserves a simple answer, but talks with Bohr just did not consist of discrete points nor did they proceed along a straight line or any other one-dimensional curve. Their topology can be best described by a multiple Riemann surface with many complicated branch cuts. And to make it more interesting Bohr liked to trace out this surface by frequent and rather arbitrary jumps from any sheet to any other. It took some time before I became used to this procedure and started to grasp the connectivity of his thoughts. Sometimes, after a long discussion, I left in complete exhaustion with a feeling of utmost confusion, and it came as a peculiar after effect when, all of a sudden, I realized how much I had learned from him.

Almost unintentionally, I found myself one day engrossed in calculations on the stopping power and the energy loss of charged particles in their penetration through matter, a problem practically unknown to me before I came to Copenhagen, but with which, to my own surprise, I now felt quite familiar. I want to tell you a little about this topic for three reasons: The first is that I happen to know something about it; the second is because it was always of great interest to Bohr; and the third is that it serves as a fine example of his way of clarifying any question.

The problem, as you know, is a classical one. It was first taken up by J. J. Thompson in 1906, even before the atomic nucleus was discovered.

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Much later Bohr wrote about it: "It has been an important test of the methods of atomic mechanics and has, not least, offered instructive lessons as regards the extent to which the application of classical mechanical concepts is adequate and at what point proper quantum mechanical analysis is required."

His fundamental paper on the subject appeared in 1913 in the *Philosophical Magazine*, just one volume ahead of his first paper on the constitution

The four speakers at the Niels Bohr Memorial Session of the American Physical Society's spring meeting in Washington, John A. Wheeler, Léon Rosenfeld, J. Rud Nielsen, and Felix Bloch, are shown with Aage Bohr, director of the Institute for Theoretical Physics in Copenhagen (whose remarks at the session honoring his father's memory are reproduced below), and with the president of the Society, John H. Williams of the University of Minnesota, who was chairman of the session.

Remarks of Aage Bohr at Niels Bohr Memorial Session

I would like to express my gratitude to the American Physical Society and also to the Bell Telephone Laboratories for inviting me to come over to this meeting and giving me the opportunity to be present at this session tonight. I need not say how closely connected my father felt to the community of physicists in this country. He came to the United States for the first time forty years ago and returned with increasing frequency as the activities here in the field of atomic and nuclear physics underwent such a rapid and great expansion. Both he and my mother, who often came with him, felt deeply attached to this country where they found so many close friends.

Over the years a large number of American physicists have also come to join the work in the Institute for Theoretical Physics in Copenhagen. They have given great stimulation to the activities of the Institute, which has been highly appreciated by my father and by our whole group. Many of us have also had the opportunity to work for a time in this country. We hope that this intimate collaboration will continue to develop in the future.

On this occasion I would also like to recall the generous support given to the Institute by American foundations. On his first visit to the United States my father received a grant from the International Education Board to enlarge the facilities of the Institute, and the Rockefeller Foundation for many years supported the activities of the Institute through grants and fellowships. In recent years, the Ford Foundation has made funds available to the Institute enabling it to expand and strengthen its endeavors in the field of international cooperation.

Under very special circumstances my father came to work in this country during the last years of the war, and I had then the experience to be with him here for the first time. The grave problems which arose from the discoveries in nuclear physics occupied my father very deeply; they were, I believe, foremost in his mind during the last twenty years. He had great visions as to the opportunities which these discoveries offer. In his hopes for an open world he attached much significance to what could be achieved through cooperation in science on a world-wide basis. Such cooperation was, from the founding of his Institute, an essential part of its endeavors and a tradition we shall do our best to continue. It is indeed an aspect of science which gives added scope and content to the work.

of atoms. The energy transfer of a fast moving particle to the atoms of the penetrated material is here thoroughly investigated in terms of classical mechanics, assuming elastic binding of the atomic electrons. The binding is essential to limit the effective region of energy transfer around the path of the particle since for atoms beyond a sufficient distance there merely occurs a temporary adiabatic displacement of the electrons without resulting energy change. In the other limiting case of atoms, very close to the path, the binding has a negligible effect during the short interaction time so that one deals in a moving coordinate system with Rutherford scattering of the electrons in the Coulomb field of the particle.

Although it contained all the important features, Bohr's final result gave consistently too large values in comparison to the measured energy loss of alpha and beta particles, and it represented a major advance when Bethe succeeded in 1930 in obtaining a more accurate formula, derived by a consistent quantum-mechanical perturbation treatment. It was by no means obvious, however, why it differed from Bohr's classical result, apart from the obvious minor change that the elastic binding of the electrons was replaced by the effect of virtual harmonic oscillators. It was clear, therefore, that the essential difference had to arise from the close collisions where one deals with the scattering of free electrons. Yet, Bethe's perturbation method corresponds to the treatment of these processes by the Born approximation, and it so happens that the expression for the scattering cross section, obtained both in this approximation and by the rigorous treatment of Gordon, agrees with the Rutherford formula which lead to Bohr's original result. It required a rather subtle analysis to understand that the knowledge of the cross section (i.e., of the intensity of the scattered wave) was insufficient and that its phase-variation was of equal importance. Although primarily a matter of pedagogical interest, it pleased Bohr that I was able to recast the problem and thereby to obtain a formula which contained Bohr's and Bethe's results as opposite limiting cases, the former corresponding to the rapid phase-variation of classical mechanics, the latter to the negligible variation implied in the Born approximation.

To most people this would have seemed to be the end of the story, but not to Bohr. In 1933, when I published my results in the *Annalen der Physik*, I added upon his request a footnote stating that in the near future ("demnächst") there would appear a paper in which he would clarify the basic features underlying these problems. It turned out that, in this particular context, "demnächst" meant fifteen years. But Bohr has kept his promise splendidly. Most of you probably know his comprehensive monograph of 150 pages on the subject which appeared in 1948 in the communications of the Danish Royal Academy. Actually, Bohr had already prepared it in 1942, but the postponement, caused by the war and his flight from Denmark, permitted him later to include in the discussion the interesting new features which appear in the penetration of highly charged fission fragments. He came back to this problem on several other occasions up to 1954 and you see, in fact, that from his early years on it never ceased to fascinate him.

Yet it represents only one of the many interests which he pursued with equal steadfastness and with a colossal memory throughout his life. As another example, I want to mention our discussions, together with Rosenfeld, on the puzzle of superconductivity which took place, off and on, over many years. On a fairly recent visit of mine to Copenhagen, Bohr mentioned to me a remark which I had made, as he put it, "the other day". Indeed, it sounded to me faintly like the sort of thing I might have said on some earlier occasion, and then I remembered that "the other day" was about 25 years ago.

I have given you only a short and most fragmentary account of my reminiscences of Niels Bohr and I am fully aware of its inadequacy to do justice to his great and lasting impression upon all those who have had the good fortune to be associated with him. Nevertheless you may find a clue to the cause of this phenomenon in the few typical instances which I selected. The faithfulness with which he persisted to develop his different lines of thought makes his life's work appear like a marvelous tapestry which is woven of many strands, none ever lost and all together forming a great unit. In want of a better word, I should like to call this unit "wisdom" and if one sometimes hears Bohr described as a philosopher, one might remember that the word wisdom (sophia) is used only in the singular form. With all his love for details and his masterful way of dealing with them, no particular insight, once gained, stood isolated in his mind. In this age of extreme specialization, Niels Bohr has re-established the awareness of that which he chose for the title of his address at the Columbia Bicentennial in 1954 and which he personified to the highest degree: The Unity of Knowledge.