*Encounters and Conversations with Albert Einstein**

The city of Ulm, where Albert Einstein was born, and the Einstein Building of the Ulm public high school, are certainly suitable places in which to tell of encounters and conversations with Einstein. The word *encounters* here must be taken to refer, not only to personal meetings, but also to encounters with Einstein's work, and even quite early on such encounters played a part in my life.

Let me begin, therefore, with the earliest event of this kind that I am able to remember. I was fifteen years old at the time, a student at the Max-Gymnasium in Munich, and had a great interest in mathematical questions. There came into my hands one day a slim volume, containing a collection of scientific articles, in which Einstein had presented in popular form his special theory of relativity. I had met the name Einstein occasionally in the newspapers, and had also heard of the theory of relativity, of which I had gathered that it was extraordinarily hard to understand. I

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found this a special attraction, of course, and so attempted to make a most thorough study of this small work. After some time I thought I had quite understood the mathematics—at bottom, after all, it involves only a particularly simple case of the Lorentz transformation—but I soon realized that the real difficulties of this theory lay elsewhere. I was called upon to recognize that the concept of simultaneity is problematic, and that in the end the question whether two events at different places are simultaneous depends on the state of motion of the observer. I found it extraordinarily difficult to think my way into this set of problems, and even the fact that Einstein had seasoned his text on occasion with such interjections as "dear reader" in no way made understanding easier. I was left, nonetheless, with a clear sense of what Einstein was after, a realization that his claims quite plainly involved no internal contradictions, and lastly, of course, a burning desire to penetrate more deeply into relativity theory at a later date. I therefore resolved, during my subsequent studies at the university, at any rate to attend lectures on Einstein's theory of relativity.

Thus my original wish to study mathematics was imperceptibly diverted toward theoretical physics, of which at that time I still knew very little. But I had the great good fortune, at the outset of my studies, to encounter an outstanding teacher, Arnold Sommerfeld of Munich, and the fact that he was an enthusiastic exponent of relativity theory, and also had close personal contacts with Einstein, provided the best of auspices for my initiation, in every detail, into this new field of science. It was a not infrequent occurrence for Sommerfeld to read out to his seminar letters that he had just previously received from Einstein, and for the whole class to be then exhorted to understand and interpret Einstein's text. Even today, I still recall such discussions with great pleasure, and from Sommerfeld's observations I eventually came to feel that I already knew Einstein a little, too, in an almost personal way, although I had never yet seen him. Now before recounting my initial, albeit abortive, attempt to become personally acquainted with Einstein, I must first say something of another field of science which at that time held me in thrall, and in which the name of Einstein also plays an important part.

The central interest of my teacher Sommerfeld, even in his own research, was atomic theory, and more precisely that application of quantum theory and the atom concept whereby Niels Bohr, in 1913, had taken the decisive step into modern atomic physics. I was attending Sommerfeld's lectures and seminars on this subject from my earliest days as a student, although I had certainly not yet acquired the qualifications for doing so. But the fascination emanating from Sommerfeld's passionate interest in these questions made up for many a disappointment that arose when the effort to understand proved fruitless. In this connection, there was much talk of Einstein's hypothesis of light-quanta, and I must explain what that was about. In Sommerfeld's lecture course we first learned the traditional view, which had been generally accepted since Maxwell's day, that light can be interpreted as an electromagnetic wave motion, differing only in its wave-length from radio waves on the one hand, and Röntgen rays on the other. In contrast to this, Einstein, in keeping with Planck's quantum theory, and on the basis of particular experiments on the photoelectric effect, had put forward the hypothesis that light consists of very small energy-quanta, and that a light-ray can therefore be compared to a hail of many tiny pellets. These two views were so radically different that I could make nothing at all of Sommerfeld's assurance that both ideas seemed to possess a certain element of truth. Einstein had again come up with a claim which called in question all the basic assertions of earlier physics; but this time there was also no proof that the new viewpoint did not lead to internal contradictions. On the contrary, the interference phenomena so frequently observed and studied seemed to stand in unbridgeable conflict with the hypothesis of light-quanta. But in atomic physics there were other such insoluble contradictions as well. According to Bohr, the atom consisted of a relatively heavy atomic nucleus, surrounded by electrons, just as the sun is girdled with planets. To this planetary system the same mechanical laws were applied as those used in astronomy, namely, the laws of Newtonian mechanics. At the same time, however, it was claimed that there could only be quite specific electron pathways, marked out by quantum conditions. This statement contradicted Newtonian mechanics, since according to the latter, an external perturbation could easily convert a quantum orbit into one that was not permissible in quantum theory. But in reality, it seemed, for example, that an incoming light beam would lift the electron discontinuously from one quantum orbit to another. At this point, too, along came Einstein with his hypothesis of light-quanta; he held the process of light emission or absorption to be a statistical one, in which light-quanta are ejected or admitted by the atom with a certain frequency. The frequencies for such processes were determined by so-called transition probabilities, and Einstein, in a celebrated memoir of 1918, had succeeded in deriving from this notion Planck's law of thermal radiation.

In the early years of my studies, therefore, when I was trying to penetrate deeper into what was then modern physics, I kept on running into Einstein's name and work, and the wish to be personally acquainted with the author of so many new ideas kept growing from year to year. But my first attempt to see this wish fulfilled proved a failure. It was in the summer of 1922. The Society of German Scientists and Physicians had announced that, at the congress to be held in Leipzig, Einstein was to give one of the main addresses, and this on the general theory of relativity. Sommerfeld suggested to me that I should visit this session and attend Einstein's lecture; he would then introduce me to Einstein in person. But it was a time of political unrest. The bitterness at Germany's defeat in World War I, and at the harsh conditions imposed by the victors, had not yet died away, and disagreement about what was to be done repeatedly led to severe civil disturbances. At this time, too, there appeared the first symptoms of anti-Semitism, which were stirred up by right-wing radical groups.

In the summer of 1922, shortly before this scientific congress in Leipzig, the then foreign minister, Walther Rathenau, was murdered by nationalist terrorists. It was a deliberate attempt to prevent any effort at a settlement. Political passions again flared high, and the anti-Semitic movement began to direct its vengeance upon Einstein too, since he was a Jew, and enjoyed an especially high esteem in the learned world of Germany. So just before the Leipzig session it was decided, at Einstein's request, that he himself should not speak there, but that von Laue should take over his lecture. I did not know this when I went to Leipzig, and merely wondered at the ominous political excitement that was to be sensed among most of those attending the session. When I sought to enter the great assembly hall, in order to listen to Einstein's lecture, a young man thrust into my hand a red leaflet, reading more or less to the effect that the theory of relativity was a totally unproved Jewish speculation, and that it had been undeservedly played up only through the puffery of Jewish newspapers on behalf of Einstein, a fellow-member of their race. I thought at first that this was the work of one of those lunatics, who do, of course, occasionally frequent such meetings. But when I found that the red leaflet was being distributed by the students of one of the most respected of German experimental physicists, obviously with his approval, one of my dearest hopes disintegrated. So science, too, could be poisoned by political passions; so even here it was not always a question solely of truth. I became so agitated that I could no longer really take in the lecture. I was sitting in the hall a long way from the rostrum, and quite failed to observe that von Laue was speaking in place of Einstein. Even after the meeting I made no attempt to seek out Einstein's acquaintance, but boarded the first train back to Munich. My first personal encounter with Einstein did not occur for another four years, during which great and incisive changes took place in physics.

Of these changes, a brief word must now be said. The contradictions that I mentioned earlier, which had arisen in the quantum theory of atomic structure, had become ever crasser and more insoluble as time went on. New experiments, for example the so-called Compton effect and the Stern-Gerlach effect, had shown that without a radical change in the forming of physical concepts such phenomena can no longer be described. In this situation I thought of an idea that I had read in Einstein's work, namely the requirement that a physical theory should contain only quantities that can be directly observed. This requirement, so the idea went, provided a guarantee of connections between the mathematical formulae and the phenomena. The following-out of this notion led to a mathematical formalism which really seemed to fit the atomistic phenomena. In conjunction with Born, Jordan and Dirac, it was then elaborated into a closed quantum mechanics, and appeared so convincing that there really could be no further doubt of its correctness. But we still did not know how this quantum mechanics should be interpreted, how we should talk about its content.

At this time, in early 1926, I was invited by the Berlin physicists to speak at the colloquium there on the new quantum mechanics. Berlin was then the citadel of physics in Germany. Here Planck, von Laue, Nernst and above all Einstein were teaching. Here Planck had discovered the quantum theory, and Rubens had confirmed it by his measurements of thermal radiation. And here Einstein, in 1916, had formulated the general theory of relativity and the theory of gravitation. Einstein would thus be in the audience; I would make his personal acquaintance. It goes without saying, that I now prepared my lecture with the greatest care. For I wanted, in any event, to make myself intelligible, and more especially to get Einstein interested in the new possibilities. The lecture went off more or less as desired; there were good and helpful questions asked in the discussion that followed. I saw that I had secured Einstein's interest, when immediately afterwards he invited me to come home with him, so that there we might discuss the problems of quantum theory more thoroughly and without distraction.

For the first time, therefore, I now had an opportunity to talk with Einstein himself. On the way home, he questioned me about my background, my studies with Sommerfeld. But on arrival he at once began with a central question about the philosophical foundation of the new quantum mechanics. He pointed out to me that in my mathematical description the notion of "electron path" did not occur at all, but that in a cloud-chamber the track of the electron can of course be observed directly. It seemed to him absurd to claim that there was indeed an electron path in the cloud-chamber, but none in the interior of the atom. The notion of a path could not be dependent, after all, on the size of the space in which the electron's movements were occurring. I defended myself to begin with by justifying in detail the necessity for abandoning the path concept within the interior of the atom. I pointed out that we cannot, in fact, observe such a path; what we actually record are frequencies of the light radiated by the atom, intensities and transition-probabilities, but no actual path. And since it is but rational to introduce into a theory only such quantities as can be directly observed, the concept of electron paths ought not, in fact, to figure in the theory.

To my astonishment, Einstein was not at all satisfied with this argument. He thought that every theory in fact contains unobservable quantities. The principle of employing only observable quantities simply cannot be consistently carried out. And when I objected that in this I had merely been applying the type of philosophy that he, too, had made the basis of his special theory of relativity, he answered simply: "Perhaps I did use such philosophy earlier, and also wrote it, but it is nonsense all the same." Thus Einstein had meanwhile revised his philosophical position on this point. He pointed out to me that the very concept of observation was itself already problematic. Every observation, so he argued, presupposes that there is an unambiguous connection known to us, between the phenomenon to be observed and the sensation which eventually penetrates into our consciousness. But we can only be sure of this connection, if we know the natural laws by which it is determined. If, however, as is obviously the case in modern atomic physics, these laws have to be called in question, then even the concept of "observation" loses its clear meaning. In that case it is theory which first determines what can be observed. These considerations were quite new to me, and made a deep impression on me at the time; they also played an important part later in my own work, and have proved extraordinarily fruitful in the development of the new physics.

Our conversation now turned to the special question of what happens in the passage of the electron from one stationary state to another. The electron might suddenly and discontinuously leap from one quantum orbit to the other, emitting a light-quantum as it does so, or it might, like a radio transmitter, beam out a wave-motion in continuous fashion. In the first case there is no accounting for the interference phenomena that have often enough been observed; in the second, we cannot explain the fact of sharp line-frequencies. In reply to Einstein's question I fell back here upon Bohr's position, that we are, of course, dealing with phenomena that lie far beyond the realm of everyday experience, and so cannot expect these phenomena to be describable in terms of the traditional concepts. But Einstein was not altogether happy with this excuse; he wanted to know in what quantum state, then, the continuous emission of a wave was supposed to take place. I then produced the comparison with a film, in which the transition from one picture to another often does not occur suddenly, the first picture becoming slowly weaker, the second slowly stronger, so that in an intermediate state we do not know which picture is intended. Thus in the atom also, a situation could arise in which for a time we do not know which quantum state the electron is in. But with this interpretation Einstein was far less happy still. It could not possibly be a matter of our knowledge of the atom, since it could perfectly well happen that two different physicists know something different about the atom, even though one and the same atom is in question. Einstein scented at once, no doubt, that in this way we were approaching an interpretation in which the statistical character of natural laws is in principle acknowledged. For in statistics it is actually a matter of our incomplete knowledge of a system. But he wanted nothing to do with this, although he himself, in his paper of 1918, had introduced such statistical concepts. He was not willing, however, to grant them any intrinsic significance. I, too, had no idea what to do just then, and we separated in the common conviction that a great deal of work still needed to be done before reaching a full understanding of the quantum theory.

Great changes again took place before we met again, in the autumn of 1927, at the Solvay Congress in Brussels. In 1926, on the basis of earlier attempts by de Broglie, Schrödinger had developed his wave mechanics, and proved its mathematical equivalence to quantum mechanics. But his subsequent attempt at simply replacing the electrons by matter waves proved a failure, and there remained the paradox, that electrons can actually be both particles and waves. The spring of 1927 then saw the birth of the so-called uncertainty relations, whereby the transition to a statistical interpretation of quantum theory was finally completed. And hence they now formed the main topic of the discussion in Brussels. As I have already said, Einstein was unwilling to recognize the statistical interpretation; so he repeatedly tried to refute the uncertainty relations. These relations involve the statement that two determinants of a system, which must both be known at once in classical physics, in order to determine the system completely, cannot, in quantum theory, be exactly known at the same moment; and hence that between the uncertainties or inexactitudes of these quantities there are mathematical relations which prevent an exact knowledge of both quantities. Einstein therefore kept on trying, during the congress, to refute the uncertainty relations by means of counter-examples, which he formulated in the shape of thought-experiments. We were all living in the same hotel, and Einstein was in the habit of bringing along to breakfast a proposal of this kind, which then had to be analysed. Einstein, Bohr and I would usually make our way to the congress hall together, so that even on this short walk a beginning could be made on analysing and clarifying the assumptions. In the course of the day, Bohr, Pauli and I would frequently discuss Einstein's proposal, so that already by dinner-time we could prove that his thought-experiments were consistent with the uncertainty relations, and so could not be used to refute them. Einstein admitted this, but next morning brought along to breakfast a new thought-experiment, generally more complicated than the previous one, which was now to effect the refutation. The new proposal fared no better than the old; by dinner time it could be disproved. And so it went on for several days. In the end we—that is, Bohr, Pauli and I—knew that we could now be sure of our ground, and Einstein understood that the new interpretation of quantum mechanics cannot be refuted so simply. But he still stood by his watchword, which he clothed in the words: "God does not play at dice." To which Bohr could only answer: "But still, it cannot be for us to tell God, how he is to run the world."

Three years later, in 1930, there was another Solvay Congress in Brussels, at which the same questions were discussed, and the general outcome was also much the same. Bohr endeavored, with great effort, and careful attention to Einstein's observations, to convince him of the correctness of the new interpretation of quantum theory; but without success. Even the very precise written analysis of Einstein's latest thought-experiments, in which Bohr employed the general theory of relativity for his proof, was unable to persuade Einstein. So there we had to leave it, united in being of different opinions. "We agreed to disagree," as the British say.

I then, unfortunately, did not meet Einstein for many years. For in the meantime the political horizon had again darkened; the National Socialists had come to power in Germany, and to Einstein it was plain that he neither could nor would remain any longer in Germany. He therefore spent a great deal of his time in travel abroad. Many universities all over the world counted themselves lucky if they could secure Einstein as a lecturer, or for a longer visit. The National Socialist revolution of 1933 then wrote *finis* to Einstein's stay in Germany. After various intermediate stops he eventually emigrated to the United States, where he accepted a chair at The Institute for Advanced Study. Here, over the last two decades of his life, he found a lasting refuge, and had leisure there to pursue the philosophical problems which preoccupied him, either in physics or in the field of political controversy. But the unrest of the period did not stop short, of course, even at the perimeter of the Princeton campus, and so in 1939, when the war began, Einstein became involved in political problems of the greatest moment, probably against his real wishes. Hence, in order not to leave the portrait of Einstein all too imcomplete, something should doubtless be said of his attitude to politics, or to public life in general, although I never talked with him on this subject.

At first sight, his position on these general questions appears extremely contradictory. One of his most careful biographers, the Englishman Ronald Clark, writes of him: "Einstein became the great contradiction; the German who detested the Germans; the pacifist who encouraged men to arms and played a significant part in the birth of nuclear weapons; the Zionist who wished to placate the Arabs,"* and who, we have to add, was an emigrant, not to Israel, but to America. We do not, however, wish merely to acquiesce in these contradictions, but must try to discover more exactly the motives that prompted him, in order to come closer to an understanding of his personality.

Einstein had already identified himself as a pacifist early on. He was already supporting the pacifist movement at the beginning of World War I, and in the twenties was still persuaded that nationalism was the main cause of wars. Thus he hoped that with a waning of nationalism the preconditions for a longer lasting peace could be created. He only recognised quite late that even the nascent political movements of the twentieth century, which he partly approved and partly recoiled from, were leading in the event to the formation of great totalitarian power-complexes, which, though no longer national states in the old sense, were nevertheless determined to enforce their claims with a military armament which far surpassed that of the earlier national states. Thus it was only in 1939, with the onset of World War II, that Einstein was really confronted with the problem of pacifism. Even in 1929, he had stated, in reply to a Prague newspaper, that in the event of a new war he would refuse to perform military service. Ten years later he had to ask himself whether this attitude was still justified,

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* Ronald W. Clark, *Einstein: The Life and Times.* London, New York, 1971, p. 20.

when Hitler and the National Socialists stood upon the other side.

To understand Einstein's answer here, it will be necessary to reflect upon the concept of pacifism. Two attitudes can perhaps be distinguished, which may be designated as extreme or realistic pacifism. The extreme pacifist refuses to participate in military service of any kind, even when the human group to which he belongs, or in which he has decided to live, is most seriously threatened; on such an occasion, he is ready even to surrender himself to destruction, or he tries to flee, till he finds some land upon earth that can offer him asylum. The realistic pacifist makes his decision harder for himself. He believes that in the event of a conflict he should first make an independent judgment of the merits of the case; he knows that these are very differently viewed by the two parties, and he tries, precisely, to see the matter at issue from the other side as well. He knows, moreover, that peace can only be preserved if each of the two sides is ready to make painful concessions. So he tries to persuade his countrymen or fellow believers to abate their own claims, to look less favorably on their own side of the case, and hence to make real sacrifices for the preservation of peace. But if, after all, he concludes upon conscientious examination that the opposition has pitched its claims absurdly high, or that unmitigated evil is here being practised by a human group, he considers it not only his right, but even his duty, to offer resistance to the evil, with weapons if necessary. The difficulty in this second view of pacifism is, that here it is no longer sufficient to be simply in favor of peace. An independent judgment must be made upon the issues, and only then can a decision be reached as to what sacrifices may be required for peace.

In the statements of his earlier period, Einstein was undoubtedly a frequent exponent of extreme pacifism; but—as Clark's biography shows—when war broke out in 1939, he opted in his actions for the second type of pacifism. On the insistent representations of his friends, especially his former Berlin assistant Leo Szilard, he wrote three letters to President Roosevelt, and thereby contributed decisively to setting in motion the atom bomb project in the United States. And he also collaborated actively, on occasion, in the work on this project. He had thus arrived at the conviction, that with Hitler a power so evil had erupted into world history, that it was right and proper to oppose this power, even by the most fearsome means. This was his decision. A French writer once said: "In critical times, the hardest thing is, not to do the right thing, but to know what the right thing is." But at this point I should like once more to drop the question of Einstein's political attitudes, particularly since I never myself discussed such difficult problems with him.

Since I am to tell of my encounters with Einstein, I should not omit to mention a little episode that occurred during the war in the Swabian town of Hechingen. My institute, that is, the Kaiser Wilhelm Institute for Physics in Berlin-Dahlem, was engaged during the war in work on the construction of an atomic reactor. Owing to the increasingly heavy air attacks on Berlin, it had to be evacuated to South Germany in 1943, and found refuge in the little town of Hechingen, in southern Württemberg, in the premises of a textile factory. The staff were billeted here and there among the townsfolk of Hechingen, and chance willed it that I was allotted two rooms in the spacious house of a textile manufacturer. Some weeks later, when I had become better acquainted with the owner, he drew my attention one day to a small house lying diagonally opposite. "Look," said he, "that house belongs to the Einstein family." It was not, indeed, a question of the direct ancestors of the celebrated physicist, but of another branch of the family, who had in fact been living in Swabia for several centuries past. So in spite of his aversion to Germany, Einstein was a regular Swabian. And we may indeed suppose that the uncommon philosophical and artistic activity of this German clan has left its traces, also, in Einstein's thought.

After the war, I met Einstein only on one more occasion, some months before his death. In the fall of 1954, I made a lecture tour in the United States, and Einstein invited me to visit him at his home in Princeton. He was then living in a pleasantly unpretentious one-family house with a small garden on the edge of the Princeton University campus, and the tall trees and park-like approaches to the campus were ablaze on the day of my visit with the vivid reds and yellows of late October. I had been warned beforehand that my visit should last only a short time, since Einstein was obliged to spare himself, on account of a heart condition. Einstein, however, would have none of this, and with coffee and cakes I was made to spend almost the whole afternoon with him. Of politics we said nothing. Einstein's whole interest was focused on the interpretation of quantum theory, which continued to disturb him, just as it had done in Brussels twenty-five years before. I tried to secure Einstein's interest in my view by telling him of my attempts at a unified field-theory, on which he, too, had concentrated the labor of many years. I did not believe, to be sure, that quantum theory could, as Einstein hoped, be regarded as a consequence of field-theory; I thought, on the contrary, that a unified field-theory of matter, and hence of elementary particles, could be constructed only on the basis of quantum theory. The latter, with all its disconcerting paradoxes, was thus the true foundation of modern physics. But Einstein was unwilling to grant so fundamental a role to a statistical theory. He held, indeed, that in the present state of knowledge it is the best account of atomic phenomena, but was not prepared to accept it as the final formulation of these natural laws. The remark "But you cannot believe, surely, that God plays at dice" was several times repeated, almost as a reproach. At bottom, indeed, the difference between the two viewpoints lay somewhat deeper. In his earlier physics, Einstein could always set out from the idea of an objective world subsisting in space and time, which we, as physicists, observe only from the outside, as it were. The laws of nature determine its course. In quantum theory this idealization was no longer possible. Here the laws of nature were dealing with temporal change of the possible and the probable. But the decisions leading from the possible to the actual can be registered only in statistical fashion, and are no longer predictable. With this the conception of reality in classical physics is basically undermined, and Einstein could no longer adjust himself to so radical a change. In the twenty-five years that had passed since the Solvay Congresses in Brussels, the two standpoints had not, therefore, come together, and even on parting we were thinking of the future development of physics with very different expectations. But Einstein was ready to accept this situation without any bitterness. He knew what enormous changes in science he had brought about in his own lifetime, and he also knew how hard it is—in science as in life—to accommodate oneself to changes of that size.