

A Personal Introduction

The great conceptual structures of atomic, kinetic and statistical physics, quantum and relativity theories, quantum mechanics and quantum field theory, and nuclear and elementary particle physics, ushered in the golden age of theoretical physics in the first several decades of the twentieth century. The profound creations of physicists like Josiah Willard Gibbs (with James Clerk Maxwell and Ludwig Boltzmann as his predecessors), Hendrik Antoon Lorentz, Max Planck, Albert Einstein, Ernest Rutherford, Niels Bohr, Arnold Sommerfeld, Louis de Broglie, Satyendra Nath Bose, Max Born, Werner Heisenberg, Pascual Jordan, Paul Adrien Maurice Dirac, Wolfgang Pauli, Erwin Schrödinger, Enrico Fermi, Lev Davidovich Landau and Peter Kapitza (and their close scientific colleagues), Hermann Weyl, Eugene Paul Wigner, John von Neumann, Oskar Klein, Hans Bethe, Felix Bloch, Rudolf Peierls, Carl D. Anderson, P.M.S. Blackett, J. Robert Oppenheimer, Victor F. Weisskopf, Hideki Yukawa, Sin-itiro Tomonaga, Willis E. Lamb, Jr., Julian Schwinger, Richard Feynman and Freeman Dyson, and their very able successors — such as Aage Bohr, Chen Ning Yang, Tsung-Dao Lee, Murray Gell-Mann (and Yuval Ne'eman), Abdus Salam, Steven Weinberg, Sheldon Glashow, Martinus Veltman and Gerard 't Hooft, and Edward Witten — not only defined the golden age of theoretical physics but became leaders of the continuing revolution in the physics of the twentieth century.

As a youth, after taking my bachelor's and master's degrees in physics and mathematics, and given my great love for literature, philosophy and history, I wanted to become a writer. I wrote about my wish to do so to my hero, the eminent English writer Aldous Huxley, and sought his guidance. I told him that although I felt a great urge to become a writer I had no theme to pursue. He immediately responded: 'You have the best of themes. You have studied quantum theory, which is the greatest revolution in human thought. Its creators are most of them still alive, work with them and learn from them how this great field developed in the twentieth century and write about it. Go and work with Pauli in Zurich!' Huxley, at that time, was having a dialogue with Wolfgang Pauli (who, apart from being a great physicist himself, had written an essay on Johannes Kepler) about the nature of the archetype of mind and personality that makes great scientific discoveries — a mixture of intelligence, intuition, inquisitiveness, imagination, as well as logic and irrationality, and a combination of method and madness — one who — in the words of the poet John Donne — 'thought with his (or her) blood,' that is, with the whole

being. Fortunately, just then I received the award of a coveted fellowship for pursuing higher studies and research in any university of Western Europe and — with Huxley's recommendation — I went to see Pauli in Switzerland. Pauli was very kind and understanding and, after the preliminaries, asked me what I wanted to do. With my still unclearly formed ideas, I told him that one day — after learning enough physics — I wished to write about the historical and conceptual development of quantum theory. Pauli said that since I had a fellowship, I could work at his institute and learn from him, but it would be very hard work; however before deciding to stay in Zurich, I must go and meet Werner Heisenberg in Göttingen because, as he said, 'It was, after all, Heisenberg who discovered quantum mechanics.' At the physics institute in Zurich, I made the acquaintance of Otto Stern (who was visiting Pauli) and Pauli's assistant Robert Schafroth and a new guest, Walter Thirring, who had just come after a stay in Göttingen; Thirring urged me to stay on in Zurich, but I followed Pauli's advice. With his introductory note to Heisenberg about my enthusiasm, I forthwith left by train for Göttingen to meet Heisenberg — whom I found to be very gentle, kind, cultivated and civilized. After a long conversation about my personal background and interests — about science, poetry and literature, history, philosophy and art — he also finally posed the question: 'With your many interests, what is it that you want to do?' I told him, just as I had told Pauli that one day — after proper training in theoretical physics — I hoped to write about the development of quantum theory in the twentieth century. Heisenberg encouraged me by saying, 'This is a most worthy and worthwhile ambition for a young man to have, and you should pursue it. But before embarking upon it, you should work on some actual problems of theoretical physics — quantum mechanics, quantum field theory, and nuclear physics [then the current interests at his Institute], and I shall be glad to guide you as much as I can when you need help. You'll find the atmosphere here [the *Max Planck-Institut für Physik* and the great intellectual tradition of the University of Göttingen] very stimulating. You are most welcome to stay.' I was greatly charmed and captivated by Heisenberg — soft-spoken, gentle, kind, perceptive, and understanding that he was. He had just celebrated his 52nd birthday; he was world-famous and a legend, and I was a mere youth, but he was not condescending. So I stayed on in Göttingen, and for the next almost three years — with a handsome fellowship — I lived as a gentleman-at-large, working on the problems that Heisenberg would assign me and going for walks in the woods with him at the edge of town, where the Institute was situated, after the seminar on quantum field theory and tea on Thursday afternoons. I would study the original scientific literature in the journals on the major problems of quantum theory and its applications, and would ply Heisenberg with questions. Upon my return to my digs at the *Akademische Burse*, I would write detailed verbatim notes on our conversation during the walk in the afternoon, and give him a copy of them on Monday morning after the seminar on nuclear physics to read and edit them. Every Wednesday I was invited for lunch at his home, and he and Mrs. Heisenberg would encourage their children to speak English with me for practice. After lunch we would repair to

Heisenberg's study, discuss my notes, and plan the program for further study and conversations, which, I would assiduously follow. This remained our program all the time when Heisenberg was in town, and not traveling on business or on vacation. I was young and forward, but very polite with a prodigious memory, and Heisenberg was young enough to remember everything which he and his scientific colleagues had done, and old enough to wish to talk about it, and in me he found someone to have engaging dialogues with. In Göttingen I got to know lots of well-known people, who either lived there or passed through to give lectures and seminars: Carl Friedrich von Weizsäcker was one of the professors at the Institute, and I spent much time with him in conversations about physics, astrophysics, philosophy, literature, history, and art; he was truly most erudite, a veritable Renaissance man. He and Heisenberg gave me introductions to go, meet and have interviews with many well-known European physicists and philosophers already during my first Spring vacation: Niels Bohr, Pascual Jordan, Friedrich Hund, Walther Gerlach, Louis de Broglie, Irène Joliot-Curie and Frédéric Joliot, Francis Perrin, Pierre Auger, Léon Rosenfeld and Lise Meitner, as well as Romano Guardini (the well-known Catholic philosopher), Karl Jaspers, Jean-Paul Sartre and Martin Heidegger, and several others, and I was able to meet and interview many of them on that occasion and others later on. It was really a grand tour for me and I returned to Göttingen deeply enriched. Max Born had just retired from the Tait Chair of Natural Philosophy in Edinburgh, Scotland, and come for a visit to Göttingen; he was looking for a place to live somewhere close to Göttingen, where he was entitled to a full pension as a former professor. During that visit he stayed for a little over two weeks in one of the well-appointed guest-rooms in the *Akademische Burse* where I had my rooms, and each morning after breakfast we used to walk to the Institute and talk about his old times there, going back to David Hilbert, Hermann Minkowski, and Felix Klein. With Born I would go on walking tours of Göttingen and its environs and see the old, great and famous city through 'Born's eyes and memories,' where he had spent such a wonderful and productive time and built a great school of atomic and quantum theory so many years ago. He told me many stories, and also gave me letters of introduction for Erwin Schrödinger, James Franck, and Walter Heitler; I would soon go to Dublin to meet Schrödinger and interview him; also in Dublin, later on, I would make the acquaintance of John L. Synge and Cornelius Lanczos, and would meet Franck somewhat later in the USA and again during a visit to Göttingen. In Göttingen, I had close contact with the venerable Otto Hahn, the discoverer of nuclear fission; he was then President of the *Max Planck Gesellschaft*; with Hahn I used to ride the same bus every evening towards our respective residences which were in the same direction; he introduced me to Lise Meitner. Among the mathematicians, I became close to Theodor Kaluza and Carl Ludwig Siegel, and went to meet Hermann Weyl, John von Neumann, and André Weil at the International Congress of Mathematicians in Amsterdam. Throughout this period, my program of study, research, and focused interviews on the development of quantum physics continued.

From Göttingen, I returned to England, where I became very close to Paul Dirac and met and had interviews with the British physicists P.M.S. Blackett, Charles Galton Darwin, H.S.W. Massey, Norman Feather, Phillip Ivor Dee, Nicholas Kemmer, C.F. Powell, John Desmond Bernal, Rudolf Peierls, James Chadwick, Dennis Sciama, and Abdus Salam, both of the latter starting their own distinguished careers, as well as M.J. Lighthill, who had attended the courses of the mathematician G.H. Hardy with Freeman Dyson at Cambridge. I had the good fortune to develop a lifelong contact with Nevill F. Mott, who had been appointed Cavendish Professor when I first met him; in my first encounter with him, he asked me what I was working on and I told him, and asked him the same question; with a grin he replied, 'Young man, I have as much time for research as the Archbishop of Canterbury has to pray!' During the following years, I would meet all the major architects of quantum theory, other than those who had passed on and laid the foundations of the field in which I would continue to work: Planck, Einstein (whom I could have met if I had been able to go to Princeton earlier, as I had tried hard to do, but he died in April 1955 when I was about to leave Göttingen for London), Ehrenfest, Sommerfeld, Kramers, and Fermi.

From Great Britain, where I had found a great career opportunity with the Department of Scientific and Industrial Research (now the Science Research Council), I went to America, where I came into close and friendly contacts with David Saxon, Leonard Schiff, Freeman J. Dyson, J. Robert Oppenheimer, Marvin Goldberger, Hans A. Bethe, Eugene P. Wigner, Richard Feynman, Julian Schwinger, Murray Gell-Mann, Victor F. Weisskopf, Willis E. Lamb, Jr., Polykarp Kusch, I.I. Rabi, Richard Hofstadter, Felix Bloch, J.H. Van Vleck, George Uhlenbeck, Samuel Goudsmit, L.H. Thomas, Y. Nambu, George Gamow, Robert Serber, S. Mandelstam, John Bardeen, Herman Feshbach, Mark Kac, R.H. Dalitz, Gregor Wentzel, S. Chandrasekhar, Edward Teller, Emilio Segrè, Robert E. Marshak, E.C. George Sudarshan, Ilya Prigogine, Charles H. Townes, Robert S. Mulliken, Chen Ning Yang, Tsung-Dao Lee, and numerous other physicists of note from whom I learned a great deal about the development of modern physics and the part they had and were playing in it. In the USA, especially since I lived close to Los Angeles, in the proximity of Hollywood Hills, where my old hero Aldous Huxley had his home, I enjoyed very close and regular contacts with him.

Like Freeman Dyson, whom I greatly admired, I did not wish to pursue work for a Ph.D., but at the University of California in Los Angeles it became clear to me that for continued rise in the academic world in America it was absolutely necessary to have the doctorate as the union card; in any case, I had done nothing so important as Dyson had in his youth when he went to pursue higher studies with Hans Bethe at Cornell, where very soon he made important discoveries. I had maintained contacts with Wolfgang Pauli throughout since our first meeting in Zurich, and had occasionally gone to visit and interview him. In 1958, Pauli came to Berkeley to give lectures on the CPT theorem and on group theory, and he was kind enough to ask me if I would come over from Los Angeles and spend

some time with him, which I immediately accepted to do. We had a wonderful time together; it was particularly instructive and endearing for me to be in close company with Pauli. I mentioned to him that I had been thinking about a problem for my doctoral thesis (on the general theory of London van der Waals forces and the Casimir effect, with the covariant perturbation-theoretical methods of Feynman and Schwinger), a problem in which Pauli was interested, and I asked him if I could complete my degree with him; he immediately agreed and approved the subject and the plan, so I discussed the details of my ideas with him. He thought it would make a good thesis. After Pauli's sudden death in December of that year — we met for the last time at the High Energy Physics Conference at Geneva that year — I sought to wind up my affairs in California, and took a leave of absence to complete my doctoral thesis in Switzerland, for which I received a prestigious fellowship from a European foundation. Since I had already done most of the work, it took me only one year to write it all up and take my degree, after which I was invited to stay on for another year as a Senior Lecturer; I gave my lectures in French, a language I had fallen in love with. In Switzerland, I enjoyed close contacts and friendships with Charles P. Enz, Pauli's last assistant, Markus Fierz, Pauli's successor at the ETH in Zurich, Res Jost, Josef M. Jauch, B.L. van der Waerden, Ernst C.G. Stueckelberg, the old mathematician and former Hilbert collaborator Paul Bernays, Walter Heitler, and Leon Van Hove; I also paid visits to Aage Bohr and Ben Mottelson in Copenhagen and to H.B.G. Casimir in Eindhoven, Holland.

After several years in California, I went on a trip around the world and visited many countries, including Japan and India. In Japan, I had the great pleasure of meeting and having interviews with Sin-itiro Tomonaga (whom I had already met and had conversations with in 1953 during his visit to Göttingen) and Hideki Yukawa and their collaborators; I would meet Yukawa again at a special conference on particles and fields, organized by Robert Marshak in Rochester, New York, in August 1967. In Tokyo I also met R. Kubo and Taro Kihara, experts in statistical mechanics, for that had been my field of research with the methods of quantum field theory. In India, I made special trips to pay my respects to C.V. Raman, Satyendra Nath Bose (whom I had already met earlier in Paris with Homi Jehangir Bhabha during a visit there from Göttingen), Megh Nad Saha, and D.S. Kothari. I returned to America after visiting several countries in Europe, especially Switzerland, France, Germany, Italy (where I visited Edoardo Amaldi in Rome), Holland (where I visited Casimir) and England; in each country I paid a call on my old friends and acquaintances.

During these years my research on problems of theoretical physics (quantum mechanics, quantum field theory and statistical mechanics) continued, and my collection of interviews, notes of conversations, tapes (and their transcripts) with the architects of quantum theory, its extensions and applications continued to grow. I gave many lectures and wrote papers on various aspects of the development of quantum and relativity theories and statistical physics, and my ideas and plans

to write a major work on the historical and conceptual development of quantum theory began to take firmer shape.

This brings me to a fateful encounter. In late summer 1969, while I was on an extended visit to Europe, Heisenberg invited me to stop by in Munich, where a decade previously he had moved the *Max Planck-Institut für Physik* from Göttingen. There he told me about Helmut Rechenberg, his last doctoral student (who had done a thesis on problems of quantum field theory), and about Rechenberg's interests in the cultural, historical and conceptual aspects of modern physics (especially quantum theory), and suggested that it might be profitable for him to join me for a couple of years to become interested in my field and goals at The University of Texas at Austin, where I then was, and do some research in elementary particle physics as well at the Center for Particle Theory. I liked the idea, especially Heisenberg's forceful recommendation, and the next day I met with Helmut Rechenberg; we had a long walk and talk for several hours in the English Garden, which we continued at dinner in an Italian restaurant in the Schwabing district of Munich. We agreed that Rechenberg would join us in Austin, Texas, by early Spring 1970, and divide his time equally in research on elementary particle theory and the historical development of quantum theory. In Austin, he became thoroughly familiar with my archives, which he assisted me in properly organizing, and became very enthusiastic about my project. With Rechenberg I worked out a detailed outline for a major work (in several volumes), *The Historical Development of Quantum Theory*, and he assisted me in numerous projects on which I was engaged. I was still giving many invited lectures on the historical development of modern physics in the 20th century, but several of my friends — among them Josef M. Jauch, Ilya Prigogine, Léon Rosenfeld and the writer C.P. Snow (who came to Austin at my invitation to inaugurate the program I had organized at the University on 'The Public Understanding of Science,' and whom I had known and been friends with ever since he interviewed me for my first job with the Science Research Council in London) — insisted that I get on immediately with the writing of my major project, which I had conceived as a youth; time passes fast, they all said, and there was none to waste. I wound up my work in Austin, and accepted professorships at the University of Geneva (sponsored by J.M. Jauch) and the International Solvay Institutes in Brussels (sponsored by Ilya Prigogine); my task would be to do research and writing on my major work. With the blessings of Heisenberg, who personally requested the *Deutsche Forschungsgemeinschaft* to make a special research grant to Helmut Rechenberg, who joined me in Geneva in January 1975, and later on in Brussels, to collaborate on a consistent major work on the historical development of quantum theory, which got finally fully completed in six volumes (nine books), with Volume 6 reaching final completion only early in the year 2000. In 1982, the first four volumes (five books) were published (from Planck, Einstein, Bohr, and Sommerfeld to Born, Heisenberg, Jordan and Dirac); in 1987 Volume 5 (in two parts) on Schrödinger's work on wave mechanics appeared. After that we took a respite from this arduous task and worked on other projects of interest to us individually and separately. In

1994 we resumed the writing of Volume 6 (in two parts), taking the historical development of quantum theory and its extensions and applications from Fall 1926 to Fall 1941, with an Epilogue (1942–1999). Most of the physicists whom I encountered at various times, many of whom became my close personal friends, as well as others, have made their appearance in *The Historical Development of Quantum Theory* (1900–1999). I must mention the fact that although there was no dearth of excellent publishers wishing to publish our work, we chose Springer-Verlag New York, who were particularly enthusiastic and offered us an open-ended contract with no deadlines; we are grateful to them for their excellent work and cooperation in producing this major work.

Since April 1970, my friendship, collaboration, and co-authorship with Helmut Rechenberg has been loyal, continuous, and sustained, and together I believe that we have accomplished a certain amount. I can truly say that the vision of my youth, first inspired by Aldous Huxley and encouraged by Pauli, Heisenberg, and Dirac, of writing a rigorous and detailed account of the historical and conceptual development of quantum theory and its many extensions and applications, could not have been achieved without the sustained collaboration and unflinching support of Helmut Rechenberg — certainly not in the form it ultimately took; this book, *The Golden Age of Theoretical Physics* is dedicated to him with my profound esteem and gratitude for all of his dedicated support to our projects. His work on particle physics has been a casualty of this enterprise; he has become, in his own right, a well-known and distinguished historian of physics by his original and collaborative contributions; his knowledge of the scientific literature and his retentive memory are phenomenal, and together we have worked most fruitfully.

In this book, *The Golden Age of Theoretical Physics*, I have brought together 37 selected essays, which had originally been given as lectures at various universities in the USA, Western Europe, Japan, and India or written as articles, and a number of them published in their initial form by me; while the final revised and enlarged versions of a number of them were published with Helmut Rechenberg, and proper acknowledgment has been made in the footnotes in the beginning of each essay where his collaboration has been decisive.

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