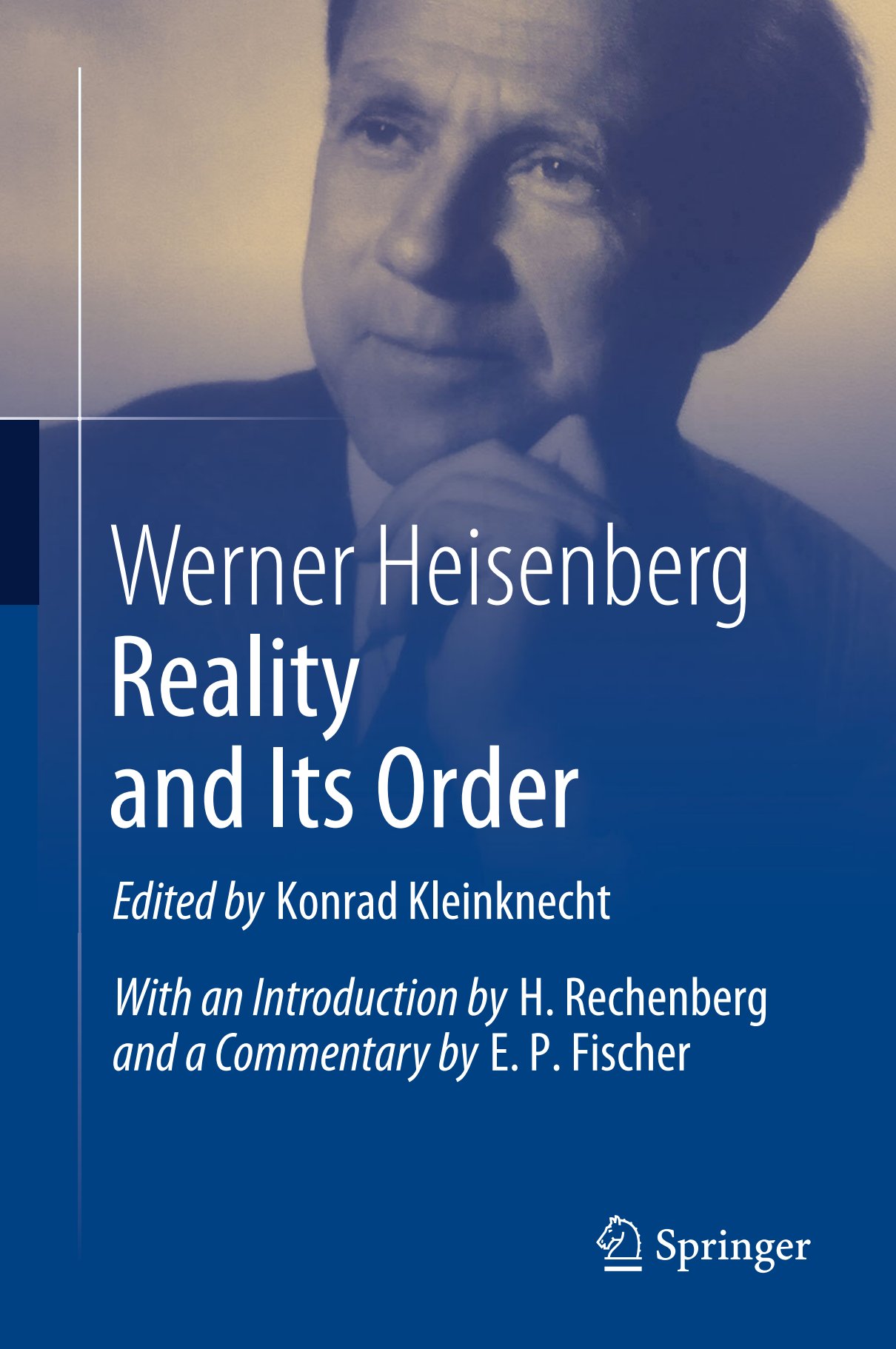


A portrait of Werner Heisenberg, a German physicist, is shown in the background. He is a middle-aged man with dark hair, wearing a suit and tie, resting his chin on his hand. The image is overlaid with a blue gradient and a white vertical line on the left side.

Werner Heisenberg Reality and Its Order

Edited by Konrad Kleinknecht

*With an Introduction by H. Rechenberg
and a Commentary by E. P. Fischer*

Reality and Its Order

Werner Heisenberg

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Translated from German by M. B. Rumscheidt,
N. Lukens and I. Heisenberg



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Author

Werner Heisenberg
München, Germany

Editor

Konrad Kleinknecht
Heisenberg-Gesellschaft
München, Bayern, Germany

Translated by

Martin B. Rumscheidt
Dover, NH, USA

Nancy Lukens
Dover, NH, USA

Irene Heisenberg
Durham, NH, USA

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Editor's Preface

Werner Heisenberg, Nobel Prize winner for his discovery of quantum mechanics and one of the eminent scientists of the twentieth century, wrote this essay during the war years 1941/42. Only relatives and reliable friends obtained a copy, but he did not think of publishing it. Considering some of the contents, this would have been very dangerous in the political situation. Therefore, the text is a sketch without references. In this essay, Heisenberg summarizes his philosophical thoughts about nature and about the question how man can know what reality is.

On July 10, 1941, Heisenberg wrote to his wife Elisabeth: "Towards evening I wrote on the private philosophy, and started the passage about the roses. I now write on these things with great enjoyment. Not always with a clear conscience, because, basically, I understand almost nothing of all these things. But since Bohr probably will not write down his thoughts, it is good that anyone who knows them is writing down what he makes of it. In Urfeld I could maybe seat myself at the little table in the bushes and also continue pursuing these thoughts".

After Heisenberg's death, the editors of his 'Collected Works' ("Gesammelte Werke") published this text under the title 'Ordnung der Wirklichkeit'. It appeared in 1989 with Piper publishers and included an introduction by Helmut Rechenberg. The Heisenberg Society issues here a new edition, for the first time in English, and with the addition of a commentary on the literary, musical, philosophical and historical background. The commentary is written by the science historian Ernst Peter Fischer. The citations [C1], [C2], etc. in Heisenberg's text alert the reader to the existence of a related comment.

The Heisenberg Society is grateful to the Heisenberg family for their permission to publish this new edition. In particular, Irene and Jochen Heisenberg have contributed in many ways to the genesis of this work, and our sincere thanks go to them. Likewise, we thank Max Rechenberg for allowing us to include the introduction by his father, Helmut Rechenberg, written in 1988. We also acknowledge the excellent work of the translators M. B. Rumscheidt and N. Lukens. For editing the book and her ever-friendly collaboration we thank Angela Lahee.

München, Germany
June 2019

Konrad Kleinknecht

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Author and Editor

About the Author

Werner Heisenberg (born 1901 in Würzburg/Germany—died 1976 in München) is one of the leading scientists of the twentieth century, inventor of quantum mechanics and Nobel Prize Winner. Heisenberg studied physics with Arnold Sommerfeld in Munich and with Max Born in Göttingen and worked as an assistant to Niels Bohr in Copenhagen. On the island of Helgoland in 1925, he made the breakthrough to a theory of the atom, dubbed Quantum Mechanics. In 1927, he found that in the atomic world, there are limits to our knowledge, which he specified as the Uncertainty Relation. In 1933, he received the Nobel Prize as “creator of the theory of Quantum Mechanics”. From 1945, he was director of the Max Planck Institute for Physics and president of the Humboldt Foundation.

About the Editor

Konrad Kleinknecht (born 1940 in Ravensburg) is professor of experimental Physics at the Johannes-Gutenberg University of Mainz and member of the excellence cluster “Universe” at the Ludwig-Maximilians-Universität München. He has worked at the universities of Heidelberg, Dortmund, Mainz and Munich, at the European Laboratory for Elementary Particle Physics CERN in Geneva/Switzerland, Caltech in Pasadena and Fermilab near Chicago and gave the Loeb lectures at Harvard. His work on elementary particle physics has been recognized by numerous awards.



Introduction

Helmut Rechenberg

Physicist Werner Heisenberg (1901–1976) is one of the great natural scientists who have given shape to how the world will view itself beyond the twentieth century. He succeeded in establishing the point of departure of today's quantum mechanics and made specific contributions to the effective description of atoms and molecules. His indeterminacy relations provided the key to the physical-epistemological interpretation of this new theory. Finally, he did decisive pioneer work in the expansion and coordination of quantum and relativity theory. Above all, he confronted problems of the innermost structure of matter. He was engaged, in other words, in what we today call nuclear and elementary particle physics.

In lectures and articles Heisenberg frequently took a position on questions that went beyond the narrower boundaries of his scholarly specialty. He particularly sought to make the findings of “modern physics,” its epistemological foundations and philosophical conclusions accessible to a broader public. This led to individual publications as well as collections of articles with such titles as “*Die Einheit des naturwissenschaftlichen Weltbildes*,” (The Unity of the View of the World in Natural Science), or “*Wandlungen in den Grundlagen der Naturwissenschaften*” (Transformations in the Foundations of the Natural Sciences). Beyond that, Heisenberg wrote three extensive texts on philosophical questions dealing with the description of nature. These are his “Gifford Lectures” delivered during the winter term of 1955/56 and

later published as a book entitled *Physik und Philosophie*, (Physics and Philosophy) 1958, 1959, his memoirs *Der Teil und das Ganze*, (The Part and the Whole) 1969, and the present extensive essay. It existed only as an untitled and undated manuscript before the publication of Heisenberg's *Gesammelte Schriften*, Collected Works. It is presented here for the first time as a separate publication.

We have titled the essay *Ordnung der Wirklichkeit*, (Reality and Its Order) in accordance with a characterizing remark by the author in the text itself. Written prior to the end of 1942, this is Heisenberg's earliest thorough and, on the other hand, thematically most encompassing statement he ever made on the philosophical and epistemological substance of the understanding modern physics has of the world. Here as never before, Heisenberg tries systematically to describe the whole of reality confronting the human being—from physical and chemical phenomena to biological systems up to the orders of society and the ideas of art and religion. Many of these questions are, indeed, touched upon again in later works or in the reminiscences of *Der Teil und das Ganze*, but they appear in *Ordnung der Wirklichkeit* in such an original and programmatic combination that we may describe this long essay as a kind of epistemological to all of Heisenberg's work.

Heisenberg's text is divided into three parts. Part I, an Introduction, outlines in three sub-sections the aforementioned "Areas of Reality," the "Language" used to describe them, and their "Order." The Main Part (II) begins with 1. introductory remarks on Goethe's poetic ordering of the areas of reality which had given Heisenberg the impetus for the essay. It then develops a six-point schema of reality and its order. The schema is built up from the lowest areas as follows: 2. Classical Physics, 3. Chemistry including quantum theory, 4. Organic Life, 5. Consciousness, 6. Symbol and Gestalt. Part III, is a Conclusion where the author comments on the political conditions of the time, giving perhaps the impression of a "Consolation of Philosophy" to his preoccupation with the order described.

It is not the task of these remarks to analyze the essay's multifaceted content; that is left to the reader. But a few references ought to be made that may help understand the text more easily and permit it to be placed into the tradition of similar writings, into its historical context and into Heisenberg's biography. Three questions are to be addressed; First: how does Heisenberg see his own place among his contemporary philosophizing physicists? Second: How and when did the present text come into being? And third: What conclusions relating to the author's special views may be drawn from the text?

The Philosophically Interested Colleagues Among Heisenberg's Circle of Physicists

The relation between physics and philosophy that had emerged from a common ground in ancient Greece had been badly affected, if not entirely dissolved, in Central Europe since the mid-nineteenth century. The exact natural sciences had energetically turned particularly against the speculative natural science of the Schelling School. Even though some significant pioneers of the new “speculation-free” physics, such as Hermann von Helmholtz or Ernst Mach, addressed important epistemological issues, physicists in general restricted themselves to their special tasks and, in so doing, deepened and expanded physical knowledge immensely. But the decisive transformations in the foundations of physics at the beginning of the twentieth century that quantum and relativity theory had brought about forced a discussion of its philosophical consequences. This was needed especially in light of the fact that early “classical physics” had found a firm place in later philosophical thought such as Newton’s mechanics in Kant’s *Critique*. Again, it was precisely those physicists who had substantially shaped the radical transformation, namely Albert Einstein and Max Planck, who were the first to contribute to the philosophical-epistemological discussion. This is not the place to address the extensive debates on the theory of relativity elicited by Einstein who was trained in Mach’s epistemological methods, nor those on the foundations and conclusions of quantum theory, debates that continue to this day. It must suffice to recall some epistemological and philosophical questions that occupied physicists in Heisenberg’s field and that emerged from the results of their work’s results.

Among Heisenberg’s physics teachers Arnold Sommerfeld hardly paid attention to philosophical problems; Max Born did so only quite late in his life. Niels Bohr (1885–1962) was a very different case. It was from him that young Heisenberg, characterized by his friend Wolfgang Pauli—and not only by him—as being “unphilosophical,” “brought home a philosophical orientation of his thinking.”¹ Bohr, the teacher, achieved success, as Pauli was later to confirm in a letter of 27 July, 1925 to Hendrik Kramers, “I also noticed with delight that Heisenberg learned a bit of philosophical thinking from Bohr in Copenhagen and now noticeably turns away from the purely formal.”

¹In a letter of 11 February, 1924, by Pauli to Bohr. The citations of letters by Pauli are taken from [1].

It is remarkable that Bohr did not really publicly address questions ranging beyond pure physics at all until about 1930. Pauli seems to have referred to the special way in which the Copenhagen physicist went about the problems of quantum physics, namely his precise and logically faultless discussion of physical phenomena and their foundations. It was that discussion Heisenberg came to know and appreciate during longer stays with Bohr before it appeared in the latter's lectures and writings for a public not specialized in physics. During the 1930s Bohr sought particularly to extend his "principle of complementarity," formulated first in 1927, from atomic physics to many other areas. This principle stated that certain phenomena permitted two wholly exclusive descriptions and viewing the two "complementary" methods of description alone yields a complete picture. Thus, he discusses chemical problems (1930), biological processes (1932, 1937, 1957, 1962), and the relation of physics to psychology (1938). He tried also to introduce the idea of complementarity into the study of human cultures (1938, 1954, 1960). Bohr's lectures and articles were collected in two volumes entitled *Atomphysik und menschliche Erkenntnis*, (Atomic Physics and Human Knowledge) (1958, 1966).

Heisenberg owes crucial insights to Bohr's epistemological-philosophical discussions. In his first publications for a general public he already follows closely in form and substance the train of thought of his teacher in atomic physics. On the occasion of Bohr's fiftieth birthday, he writes in particular:

For the scientists who had the good fortune of having the chance to work for a time in Bohr's institute in Copenhagen another aspect of Bohr's work

[besides physics per se] is almost more important. It is the creation of an intellectual center where the most diverse threads of modern natural science come together and enter into relation to the general substratum of all natural, physical and human sciences. The extraordinary personal influence Bohr had and still has on his students is rooted precisely in this unity of thought where every scientific question, just as life itself, is brought into relation to the same, unchangeable center.²

The center he speaks of is, of course, the principle of complementarity that came to occupy a central place in Heisenberg's thought.

Another founder of modern atomic physics, not one of Heisenberg's academic teachers yet influencing him increasingly through his writings

²Heisenberg [2]. Reprinted in Heisenberg [3]; cited hereafter as GS/CW with the appropriate vol. no. and date.

particularly after 1930, was Max Planck (1858–1947) the father of the quantum theory. It was especially what Planck wrote on the relation of physics to issues of philosophy, politics and religion that made its mark on Heisenberg. Only after he had turned 50 did Planck express himself on topics that went beyond the substance of physics. In 1908 he lectured in Leyden on *Die Einheit des physikalischen Weltbilds*, (The Unity of the Understanding of the World in Physics,) a polemic against the positivistic and anti-atomistic views of Ernst Mach. Others of Planck's lectures have revealing titles such as *Die Stellung der neueren Physik zur mechanistischen Weltanschauung* (1910) (The Position of Recent Physics Toward Mechanistic Interpretation of the World), *Dynamische und statistische Gesetzmässigkeit* (1914) (Dynamic and Static Regularity), *Kausalgesetz und Willensfreiheit* (1923) (The Law of Causality and the Free Will), *Positivismus und reale Aussenwelt* (1930) (Positivism and the Real Outer World), *Ursprung und Auswirkung wissenschaftlicher Ideen* (1933) (Source and Impact of the Ideas of Science), *Die Physik im Kampf um die Weltanschauung* (1935) (Physics in the Struggle for the Perception of the World), *Religion und Naturwissenschaft* (1937) (Religion and Natural Science), *Determinismus und Indeterminismus* (1938) (Determinism and Indeterminism), *Sinn und Grenzen der exakten Wissenschaften* (1941) (The Meaning and Limits of the Exact Sciences), *Warum kann Wissenschaft nicht populär sein?* (1942) (Why Can't Science be Popular?), *Wissenschaftliche Streitfragen* (1945) (Disputes and Issues in Science) and *Scheinprobleme der Wissenschaft* (1946) (Sham Problems of Science.) The very fact that this scholar, a man of integrity and respected world-wide, did not remain silent in spite of his personal rejection of the "Third Reich," in a time of great difficulty for science and scientists, but actually increased his activity as a public lecturer, gave strong intellectual and moral support to many colleagues in the field and to interested lay people.

Heisenberg's decision in 1933 to remain in Germany allowed him to move closer to Planck even though the latter's interpretation of quantum mechanics was contrary to Heisenberg's physical interpretation. In his review of Planck's anthology *Wege zur physikalischen Erkenntnis* (1933) (Pathways to Knowledge in Physics) Heisenberg concludes: "The overall impression evoked by Planck's lectures leads this reviewer to this summation: it is precisely Planck's religious-ethical perception of life that in the end determines his position vis-à-vis the epistemological situation of modern physics that permits him to walk a straight and almost too sure road even when at every turn of that road unfathomable chasms of epistemology threaten."³ What

³Heisenberg [4], reprinted in *GS/CW*, CIV, p. 239.

Heisenberg meant by the “almost too sure road” was, above all, Planck’s decisive defense of the strict validity of the law of causality.

Heisenberg’s positive review met with Pauli’s reproach. He wrote Heisenberg that he “noted with some displeasure certain phrases in the review of Planck’s book,” such as the admission that Planck’s concept of “the reality of the outer world” was a valid one. Pauli implored Heisenberg: “May the spirit that hovers over Planck’s scientific production and his personal life not gain all too much the upper hand in your publications and your life.”⁴ Pauli never forgave Planck for his polemics of 1908 against his god-father Mach. He believed that there were “qualities in Planck’s activity” that he found “deeply, not at all superficially sloppy.” He now felt that he had to criticize not only the scholarly but also the political Planck, who after the National Socialists’ take-over, tried to keep some colleagues in Germany. Heisenberg did indeed agree partially with Pauli’s objections to Planck’s philosophy but not with his reproach of Planck’s political and moral stance. A book review of 1935 concludes with these words: “Finally, Planck asserts with the entire solemnity of his being, that science, through its very nature, educates us in truthfulness. That makes him, beyond the domain of scholarly achievement, the spokesperson for German natural science. The most important and greatest task today is to guard that heritage.”⁵

Heisenberg found support in Planck’s political and human demeanor; he responded to what Planck dealt with in his lectures and articles. He often even adopted their titles despite the fact that his conclusions differed occasionally from those of his model. With Planck Heisenberg opposed the “unflinching positivists à la [Philipp] Frank,” whereas his colleague at Göttingen, Pascual Jordan (1902–1980)—almost of the same age as Heisenberg—clearly represented the positivist method. In the thirties Jordan published a sizeable number of articles seeking to draw the philosophical consequences to be derived from quantum mechanics. The titles of his books signal the direction Jordan was pursuing in. Physikalisches Denken in der neuen Zeit (1935) (The Thinking of Physics in Recent Times), Die Physik und das Geheimnis des organischen Lebens (1945) (Physics and the Mystery of Organic Life), Eiweissmoleküle (1947) (Protein Molecules), Verdrängung und Komplementarität (1947) (Displacement and Complementarity), Atom und Weltall (1952) (The Atom and the Universe), Der gescheiterte Aufstand (1956) (The Failed Revolt). With his contributions after 1930 to biology,

⁴See note 1 above; vol. 2, p. 214.

⁵Heisenberg [5], reprinted in GS/CW, vol. CIV, p. 240.

Jordan crossed the boundaries of physics as a discipline and with them helped establish the Treffertheory of genetics. He clearly was perceived in his time as a pioneer of the new interdisciplinary biophysics.

Wolfgang Pauli (1900–1958) was also aligned with positivism, especially with the epistemological-critical method of Ernst Mach. He confessed in 1954, “So as to alert the philosophers, I would like to say that I do not belong to any philosophical school that has a name ending in ‘ism,” adding that he tended “to maintain a certain middle position between extreme orientations.”⁶ Pauli himself published little about more general philosophical problems of science. His collection *Aufsätze und Vorträge über Physik und Erkenntnistheorie* (1961) (Articles and Addresses on Physics and Epistemology) contains only five items on this matter. Among them are the important articles: *Phänomen und physikalische Realität* (1954) (Phenomenon and Physical Reality), *Naturwissenschaftliche und erkenntnistheoretische Aspekte der Idee des Unbewussten* (Natural Science and Epistemological Aspects of the Idea of the Unconscious) (1954, on the occasion of C. G. Jung’s eightieth birthday) and *Die Wissenschaft und das abendländische Denken* (1955) (Science and Western Thought).

Heisenberg often profited significantly from the frank critique his friend offered to his philosophical writings. For example, Pauli caused Heisenberg to tighten a number of formulations in the essay *Der Begriff ‘abgeschlossene Theorie’ in der modernen Naturwissenschaft* (The Concept of ‘Closed Theory’ in Modern Science).⁷ For his part, Heisenberg devoted an extensive essay to presenting Pauli’s philosophical views.⁸ There he refers specifically to two completely different sides in his friend’s being and thinking. “The power of the fascination that emerges from Pauli’s analysis of problems in physics came only partly from the clarity of his formulations, transparent to the last detail, but also partly from his constant contact with the realm of productive intellectual processes [in the subconscious] for which there is yet no rational formulation.”⁹

Among Heisenberg’s younger contemporaries, his pupil Carl Friedrich von Weizsäcker, the only one to be mentioned now, showed an interest quite early in philosophical questions. He had intended initially to study philosophy but Heisenberg persuaded him to study physics first as a foundation

⁶Pauli [6]. See esp. p. 93.

⁷It appeared first in *Dialectica*, vol. 2 (1948); reprinted in *GS/CW* CI, pp. 335–340.

⁸Heisenberg [7]; reprinted in *GS/CW* CIV, pp. 113–115.

⁹See note 8; p. 113. Pauli referred in particular to Jung’s archetypes and occasionally used the symbolism of the alchemists.