





**Gerhard Wilczek**

**Important Scientists and  
Philosophers of our Times**

Translation of sections of the German volume *Bedeutende Naturwissenschaftler und Philosophen unserer Zeit*. Norderstedt 2007, ISBN 978-3-8384-2352-9

For further information on the publisher and catalogue, see [www.buchmedia.de](http://www.buchmedia.de)

March 2010

Buch&media GmbH, Munich

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Translation: Johanna Ellsworth

Cover design: Kay Fretwurst, Freienbrink

Production: Book on Demand GmbH, Norderstedt

Printed in Germany. ISBN 978-3-86520-366-3

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# Werner Heisenberg

Werner Heisenberg was born in Würzburg in December of 1901. His mother was the daughter of the principal of the Max Gymnasium in Munich. Because of that and of the evidence of love in her poetry, the little Heisenberg had come to some honours. (Elisabeth Heisenberg, *The Political Life of an Unpolitical Person*, 1980, P. 19). She gave her two boys a happy childhood. Whenever Werner felt treated in an unfair way, he would cut off every connection to the person whose treatment had displeased him and withdraw into his own world. So during his whole first school year he refused to look at a teacher who had slapped him on his finger with a stick for no reason, making the finger swell. “But that was the exception, and his benevolence, a good will and carefulness made him a fair and patient listener and adviser of others.” (ibid, P. 12). When Werner was eight years old, the family moved to Munich, in particular to a block of flats on Hohenzollernstrasse in Schwabing. The boy felt “locked up”. He and his brother built a large warship with real shotguns.

Heisenberg’s father came from Westphalia. He studied at the Ludwig-Maximilians-University in Munich and started as a teacher at a secondary school. From Munich he was transferred to Würzburg to obtain his habilitation. Werner was born in Würzburg. In January of 1910 Heisenberg’s father was recalled to Munich to hold the only professorship for middle age and new Greek philosophy in Germany.

His teachers said about young Heisenberg: “He playfully reached his achievements without any efforts. The pupil also keeps everything in a good order, he shows self-confidence and always wants to excel.” (Notes, School Year of 1912/13 and 1913/14, Grades IIA and IIIa). Later, when the most brilliant physicists would come to Heisenberg, he also believed to be spiritually superior to them all. He already showed

*Note: The book titles quoted in the following text are not the official English titles they may have been published under. In each case the German title has been translated into English for the sole purpose of clarifying the topic each book deals with.*

an active interest in physics during his first school years, even before that subject was part of his school curriculum.

“My parents had a friend, a young woman of about twenty-four. She was a chemist who wanted to make her exam for a doctor’s degree, for which she would also be tested in mathematics, and she needed to calculate with the differential and integral calculus. So she asked me if I could give her tutoring lessons. So I tutored her for three months. I don’t know whether she learned anything during those lessons, but *I* learned it in that time.” (*Armin Hermann Heisenberg*, 1994, P. 19f).

In Spring of 1917 the sixteen-year-old males were drafted to serve in the war as well.

Heisenberg and other youngsters were taken to the Grossthalerhof in Miesbach. “I can still remember the fact that I had the Critique of Pure Reason by Kant on me... Soon I was to discover that if we had worked all day, all we would want to do in the evening was sleep. But I think that this was a very important time for my education, for we experienced at this farm what work was really all about. It was not like school where you could assume that it was not all that important. At the farm we had to rise at two-thirty in the morning, and we often worked until ten at night.” (*ibid*, P. 10f).

“It was June of 1919, a warm summer, and especially early in the morning there was nothing to do. So it happened that I would often withdraw to the roof of the seminary for priests shortly after sunrise. There I would lie down with a book to get warmed by the first sun rays. One of those mornings I got the idea to take a book by Plato up to the roof. So it happened that I started to read something different from the books I had studied in school. With a relatively modest knowledge of Greek I would read the dialogue of Timaios, and from that source I got my first idea about the Greek atomists.” (*W. Heisenberg, Steps over the Boundaries*, 1977, P. 101).

Heisenberg doubtlessly regarded his philosophy as a continuation of Plato’s philosophy in his century. On the 100<sup>th</sup> Birthday of Max Planck, who was a Platonist, Heisenberg said: “According to Plato, these elementary particles are mathematical thoughts of a higher symmetry. The triangles themselves are not of matter, they are still only mathematical thoughts; the last root of the apparitions is not matter but a mathematical law, the symmetry, the mathematical form.” (*ibid*, P. 22f).

At Heisenberg's final school examination that would qualify him for university, his achievements were marked 'very good' in religious science, Latin, Greek, French, math, physics, history and physical education. German was an exception – he obtained nothing higher than 'good'. He received a scholarship for the Maximilianeum. Only his schoolmate Anton Scherer obtained an even better scholarship than Heisenberg. Werner began to study mathematics. It was expected of him to become the best in that field.

The studies at the University of Munich were eliminated for young Heisenberg when Professor Ferdinand Lindemann ruled Heisenberg to be spoiled for mathematics after having read the book *Space and Time* by Hermann Weyl. On his father's advice Heisenberg transferred to Arnold Sommerfeld who accepted him as his student. Sommerfeld specialized in theoretical physics for which classical physics were only a preliminary supposition. That meeting proved to be decisive for Heisenberg's whole life.

The breakthrough occurred in 1913 when Niels Bohr in collaboration with Max Planck discovered that natural constants are postulates of quanta. Sommerfeld adopted Bohr's idea. After Sommerfeld published his book *Atomic Building and Spectral Lines*, it became the bible of atomic physics.

"Shortly thereafter, I guess one or two weeks later, I went back to Sommerfeld and had the complete schema of terms. I came up with a result I hardly dared to present. Sommerfeld was totally shocked. I said, 'The fact is functionary if we use half of the quantum time.' No one was talking of half quantum numerals; the quantum numeral was a whole number." (A. Hermann, see above, P. 15).

Particularly important was the fact that Heisenberg found a good friend who was almost his age and eminently clever. That was the case with Wolfgang Pauli who had come to Munich with his completed work on the general theory of relativity, a fact that evoked Sommerfeld's admiration. "We were always close friends and never felt bad when one of us would criticize the other one's ideas." (ibid, P. 16). Heisenberg and Pauli were co-students for only two semesters. As early as in July of 1921 Pauli obtained his doctor's degree and graduated from the University of Munich with honours. Subsequently he went to Göttingen and later to Hamburg. Heisenberg and Pauli would exchange their ideas in the future as well; they met several times per year and corresponded

with each other on a regular basis. “Pauli and Heisenberg proved that Adolf Harnack’s saying that theoretical physics and its members are the real philosophers of the 20<sup>th</sup> Century was true.” (ibid, P. 19)

Sommerfeld was no philosopher, of course. He wrote to Einstein in 1922, “I can only promote the theory of quantum; you have to create your own philosophy.” So Heisenberg did not get the chance to learn enough about philosophy in Munich. However, he later did from Bohr in Copenhagen. The so-called Bohr Festival Performance took place in 1922. There was a series of lectures about the Quantum Theory of atoms and the periodic system of atoms in Göttingen. The lectures were followed by discussions. Heisenberg was fascinated by Bohr while Heisenberg also deeply impressed Bohr. He said, “Heisenberg understands everything.”

After the abdication of German monarchy and the lost First World War revolutionary revolts started in Germany. In Bavaria a socialistic republic took over on November 7<sup>th</sup>, 1918. It was modelled after the Soviet government yet at the beginning of May 1919 the revolt was suppressed by German Reichswehr troops.

Heisenberg’s father did not survive the assumption of power through Hitler. He had been warning others about this “muddle-headed seductive fellow”. “Never open yourself to Hitler.” (Elisabeth Heisenberg, ibid, P. 29). The father died of typhoid fever in 1930. He had been infected with the dangerous bacillus during a study trip to Saloniki.

Werner Heisenberg had stated his announcement voluntarily to support the moderate social leaders. He was serving in the cavalry protesting commando No. Eleven, delivering errands, monitoring the streets from the roof of the Catholic seminary at the university and reading Plato’s *Tmaios* in Greek language. (*Collected Works*, ibid., P. 1)

In addition to epistemology and the theory of relativity there was the book *Space and Time* by H. Weyl that impressed him so profoundly that he forgot what Professor Lindemann of the University of Munich had said. After qualifying for university, he had gone to Lindemann to get his opinion, and Lindemann had rejected him regarding the mathematics faculty because he considered Heisenberg unsuited for that subject. Professor Sommerfeld, however, arranged for a very effective combination with physics. Heisenberg described his work method to Humboldt scholars as follows: “Those who have devoted their lives to the sciences have decided to think thoughtlessly and without any

criticism yet always in doubt, to examine and stay open to any counter demonstrations.” (ibid)

“Heisenberg became the leader of a small youth group, the federation of the German new boy scouts which produced the German post-war youth movement and strived for a renewal of life in Germany. Until the time independent youth organizations were prohibited in 1933 Heisenberg would spend most of his leisure time with his group.” (Collected Works, *ibid*, P. 1f). There are even reports about trips to foreign countries, such as to Finland in summer of 1923. The youth movement gave him his love of nature and the experience of companionship. Worthwhile to remember was the stay at the Castle of Prunn that overlooked the Valley of Altmühltal. His work within the youth movement did not stop him from university education. Heisenberg eagerly worked at the Munich University extensions.

His scholarship for the Maximilianeum let him attend the University of Munich in the winter term of 1920/21. Professor Sommerfeld recognized the talent Heisenberg demonstrated in his seminar. Other members of the seminar at the time included Gregor Wentzel, Wolfgang Pauli and later on Otto Laport and Karl Reichert as well.”(ibid, P. 2). During his three years at the university Heisenberg attended lectures held by Sommerfeld who covered all areas of theoretic physics, including the quantum and the theory of relativity. Special lectures were offered by Karl Herzfeld. “He showed less interest in the lectures and exercises in the experimental physics lab of Wilhelm Wien. He visited math courses held by Lindemann, Alfred Pringsheim, Artur Rosenthal and Aurel Voss.” (ibid). And he engaged in astronomy as well.

His studies at the University of Munich were diminished by Professor Lindemann’s statement. Sommerfeld represented theoretical physics. When Heisenberg wanted to attend a lecture offered by Einstein at a convention of German scientists and physicians in Leipzig in the Summer of 1922, he was handed an anti-Jewish flyer directed especially against Einstein at the door. The author of the flyer was the renowned physicist and Nobel Prize winner Philipp Lenard. Heisenberg’s world came to an end. He did not attend. Einstein had not come to the convention, he had not appeared due to the anti-Semitic attacks, Mister of Laue held the lecture instead. On top of it all Heisenberg had been robbed in Leipzig. Later he would be forced to work as a woodcutter to earn his living.

Sommerfeld acquainted Heisenberg with the latest problems of nuclear physics and sent him to Göttingen in June of 1922. The Danish Physicist Niels Bohr lectured on an atomic model there. Heisenberg had the chance to participate in it. The “Bohr festival games” mark the development of physics. It resulted in the birth of quantum physics, and Heisenberg was able to work out his initially vague ideas. Heisenberg met the leading atom physicists of Germany and Europe, such as Max Born, Paul Ehrenfest, James Franck, Hendrik Anthony Kramers and Alfred Landé. Born invited Heisenberg to become his personal assistant in Göttingen. However, Heisenberg was still depressed, and his father wrote to him that his academic career was over for good. It was only because of Sommerfeld that Heisenberg obtained his degree with a mere *cum laude* instead of the highest honours of *magna* or *summa cum laude*.

“In October of 1923 Heisenberg became Born’s assistant at the University of Göttingen.” (ibid., P. 3). There he got his habilitation on July 28<sup>th</sup>, 1924 and was now a completely acknowledged university professor. “Heisenberg is at least as gifted as Paul is,” Born registered with astonishment. “Only two semesters ago Pauli had been his collaborator, and he never would have thought of getting such a good assistant.” (A. Hermann, see above, P. 22)

“But now I (Born) am fond of Heisenberg, cherish and appreciate him. His talent is as valuable as Pauli’s and it is enormous but in addition to that his modesty, his good temper, his eagerness and enthusiasm are particularly pleasant. The professor in Hamburg wants to get Heisenberg. I would be very sad if he went. I will spare no effort to keep him here.” (Letter from Max Born to Arnold Sommerfeld dated January 5<sup>th</sup>, 1923).

In Summer of 1923 Heisenberg found himself at the Institute of Theoretical Physics in Munich again. “Sommerfeld wants me to publish my work about turbulences.” (A. Hermann, see above, P. 23). Yet his colleague Wilhelm Wien had discovered gaps in Heisenberg’s experimental physics. “I am not sure whether Wien will let me fail my examination.” There was probably a heated discussion between Wien and Sommerfeld about Heisenberg’s physics grade but results in theoretical physics and experimental physics could be combined into one grade. Wien spoke of “a bottomless ignorance”, while Sommerfeld called Heisenberg a unique genius. Finally they agreed on a passing grade in the

minor subject of mathematics. Heisenberg received the best grade from Oscar Perron and passed his astronomy exam with Hugo von Seeliger with Grade 'good'. The reason why Heisenberg passed that subject was due to his dissertation on the hydromical explanation of turbulences which Sommerfeld commented with outstanding praise.

Göttingen was a reputable centre of mathematics run by Felix Klein and David Hilbert. Born accepted Heisenberg's thesis titled "About the changes of formal regularity of the Quantum Theory while taking the normal Zeemann effects into consideration". The habilitation was achieved only one year after the rigorosum and in addition to a barely sufficient doctor's thesis, which was extraordinary.

Heisenberg only knew the centres of atom physics in Munich, Copenhagen and Göttingen. In Spring of 1925 problems arose. Pauli wrote: "At present physics are very distracted once again. At any rate it is too difficult for me, and I wish I was a screen comedian who had never heard of physics. But now I hope that Born will save us with the help of a new idea." (ibid, P. 29). Heisenberg was very impressed with Einstein and less impressed with Ernst Bloch. It was clear that the new physics were something quite different from the existing classical physics. The emerging quantum theoretical physics were new territory that appeared at the horizon after almost insurmountable difficulties.

Heisenberg had received a Rockefeller scholarship for his first educational stay at Copenhagen during the Winter Semester of 1924/25. Because of Niels Bohr Heisenberg refused the first offer to go to Leipzig that he received in 1926. However, he did prefer staying in Germany to going to the University of Zurich. In Autumn of 1927 he set out for Leipzig. Many young talents from all over the world came to that city to see the famous professor. Leipzig, Göttingen and Copenhagen had become the centres of natural sciences.

In Copenhagen Heisenberg learned Danish and English. He also deepened his knowledge of the atom and Quantum Theory. He declared: "From Sommerfeld I got my optimism, in Göttingen I learned my math, and from Born I learned physics." (*Collected Works*, see above, P. 9). In May of 1926 Bohr offered to make Heisenberg the successor of his assistants at the Copenhagen institute. Bohr and Heisenberg proposed additional estimations. Heisenberg brought up the so-called indefiniteness relation according to himself. The interpretation

of quantum mechanics rendered by the Copenhagen group met with the agreement of most physicists; however, Albert Einstein raised objections to the interpretation.

“Heisenberg wanted to create new physics. Niels Bohr was to assist him in this. Originally we (the physicists in Göttingen) were able to speak of other things than the Quantum Theory so we were full of inner contradictions, marvelling at its successful findings.” (A. Hermann, see above, P. 36). During the Winter Term of 1925/26 Heisenberg supported Born’s lecture “Kinetic theory of matter”. Born had applied for a scholarship for Heisenberg and designated him to be a researcher that would be known to the world.

On the first of May 1926 Heisenberg started as a teacher of theoretical physics in Copenhagen. E. Schrödinger had designated the atom to be a swinging system, emerging from and by waving mechanics. Heisenberg frequently despaired when dealing with the problem. “Until now man has tried to make the dualism between waving and bodily picture a starting point of the physical interpretation while I (Heisenberg) have endeavoured for the waving mechanics to come to an end, which seemed to be indicated by quantum mechanics and Dirac’s transformation theory.” (see above, P. 38). Bohr arrived at the principle of complementary relation, and after him Heisenberg arrived at the so-called unsharpened relation. Pauli was excited and spoke of a “dawn of modern times”. Heisenberg declared: “You can perceive the world with your p-eye and you can view it with your q-eye. When I will see it with both eyes then you will get confused.” (Letter from W. Pauli dated October 19<sup>th</sup>, 1926).

The Copenhagen group published that new philosophy. The new conception influenced the theories of natural sciences. Until now the sentence that nature does not leap had been considered to be true. Now it suddenly appeared to be impossible. “We are not able to know the presence fundamentally in all determinations.” (W. Heisenberg and Niels Bohr, *The Copenhagen Interpretation of Quantum Theory*, Documents of Natural Science, Volume 4, P. 34).

From Copenhagen Heisenberg moved on to Leipzig, where he got a professorship of theoretical physics. In the beginning of 1929 Friedrich Hund joined the institute and later the mathematician Bartel Leendert van der Waer came to the institute as well. “Felix Bloch, Rudolf Peirle and Eduard Teller were among the first of Heisenberg’s students. Hans

Euler, Leon von Rosenfeld, Victor Weisskopf, Carl Friedrich von Weizsäcker, Gian Carlo Wick also became his students.“ (A. Hermann, see above, P. 57). The Leipzig university weeks came into being. The first took place in June of 1928. P. Dirac spoke about the relativistic electronic equations and Fritz London about the theory of chemical fusions. In 1933 they came to an end.

After the overthrow of power in 1933 everything changed gradually. Heisenberg received the Nobel Prize for his theory in 1933 which counted for 1932. This brought him into the limelight. Despite his different tasks he would go on journeys abroad. At the beginning of 1929 he spoke about the principles of Quantum Theory at the University of Chicago. They were published as his first book. He would visit the U.S. A. once more, accompanied by Dirac.

In 1932 he held lectures at the summer school of Ann Arbor (U. S. A.). He also lectured at different conventions, and he would often visit Niels Bohr in Copenhagen and sometimes Wolfgang Pauli in Zurich. Both were irreplaceable to him in difficult times.

Particularly the quantum mechanics led to completely new aspects of the subatomic world. The consequences of these aspects “are in contract with our whole lives”. Heisenberg’s theory began to flourish despite the political situation in Germany. Especially in Copenhagen he felt that the physicists from other countries were superior to him and that they understood modern physics better than he did. The number of his students dwindled yet he was plainly the leading speaker in Germany when it came to theoretical physics. His enthusiasm was so great that he would rarely catch a few hours of rest. When exhaustion set in, he would retire to the mountains where he went skiing or hiking. In the summer he visited Helgoland to recharge his batteries in tranquillity.

When Heisenberg decided in 1934 to support Einstein and his doctrine, a real campaign was started against him. Heisenberg was forced to advice those close to him to leave Germany. His old enemies, Lenard and Starck, called the Quantum Theory and the relativity theory as being “Jewish” and “un-German”. Heisenberg was discredited. He turned to the minister of education and science, emphasizing the significance of theoretical physics and underlining the necessity to instruct physicists. The Nobel Prize did not only change his relationships to friends but also those to his enemies. Therefore Starck delivered a strange elocution about “the tasks of the natural sciences in the new Empire” at the chemical in-

stitute at the University of Berlin. Heisenberg was considered a “formalist” who was impudent enough to get the Nobel Prize just now.

Heisenberg finished his third great work on the “building of atomic nuclear energy”. He also saw the theory of elementary particles which went beyond nuclear physics. A. Sommerfeld retired at the end of March of 1935. On the 13<sup>th</sup> and 14<sup>th</sup> of December 1935 those focusing on “German physics” got together in Heidelberg. The institute there was to be named Philipp Lenard Institute. J. Starck said in his speech, “Einstein has disappeared from Germany. But unfortunately his friends and sponsors still have the opportunity to continue in his spirit. His main supporter, Planck, can still be found on top of the list of the Emperor Wilhelm Society; it is still permitted that his interpreter and friend, von Laue, plays the role of physical appraiser of sciences at Einstein’s academy, even market by a special vocation.” (J. Starck and Philipp Lenard as German scientists, monthly NS propaganda booklets, 71/1936, P. 106ff). When the polemics were continued in the *Völkische Physik*, Heisenberg and others refused to remain silent. “We find that physics in Germany are currently in a complicated crisis. Instead of a great demand on physicists in technology and the military, there is a lack of qualified young talents. There are great problems filling faculty positions, and the number of first semester physics students is much too low. The attacks mentioned above have increased the problem even more. They keep the students away from studying physics and especially from the field of theoretical physics. Moreover these attacks considerably damage the prestige of German science abroad, as various articles by specialized editors in newspapers show.” (A. Hermann, see above, P. 57).

Still Bohr and Heisenberg, Victor F. Weisskopf and Friedrich von Weizsäcker, Edmund Teller and Otto Robert Frisch continued to collaborate. After the outbreak of World War II Weisskopf, Teller and Frisch left Germany for the United States. They worked on the American atom bomb in the Manhattan Project. Heisenberg and von Weizsäcker remained in Germany, working in the so-called Uranium Association. On the 11<sup>th</sup> of January Heisenberg wrote a letter to Bohr who was touring Japan at the time. “The situation of the world might have changed again by the time you return, and I don’t dare to predict anything for longer than a few weeks any more.” (ibid, P. 58).

Heisenberg contemplated whether to give up his lectureship. He decided to travel to Berlin to visit Max Planck and get his advice. Planck,