



# Bohr, Heisenberg, and What Michael Frayn's “Copenhagen” Tries to Tell Us

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**Bohr, Heisenberg, and What Michael Frayn's "Copenhagen" Tries to Tell Us  
by Gerald Holton**

Werner Heisenberg's unexpected visit to Niels Bohr, in September 1941 in German-occupied Denmark, was a non-event in terms of science or of history. During the 1920s, the course of physics had been changed as a result of the close interactions between these two great scientists. This time it was not. Nor had their encounter in 1941 in Copenhagen, at the height of the German Army's successes throughout Europe, any known effect on the course of the war, or on the on-going work of the nuclear scientists on either side at the time. As far as we know, whatever Heisenberg may have hoped to gain from this meeting did not occur.

**"Copenhagen"**

But on this unfruitful base, the imagination from various sides has built castles full of mystery and drama. One of these is Michael Frayn's play "Copenhagen." The author has cleverly highlighted the concept of uncertainty, associating it with his capacious speculations of what may have actually happened in that meeting. The choreography of the actors' movements, apparently meant to evoke the supposed motions of electrons in Bohr's first atomic theory, adds to the theatrical experience. The dramatist's device to start the action over and over again from the same point, as had been done earlier so successfully in Max Frisch's "Biographie," adds an hypnotizing element.

There are only three actors on the stage, representing versions of Bohr, his wife Margrethe, and Heisenberg. But they have become ghosts, recounting the extraordinary scientific breakthroughs in quantum mechanics, with asides about other remarkable physicists with whom they had collaborated or fought. Often

they become suddenly unaware of one another's presence, adding to the spooky quality of their interaction. But again and again these three return to two haunting puzzles. One is why the Germans never succeeded in building an atomic bomb. The other, perhaps connected with the first puzzle, is why Heisenberg had suddenly turned up at Bohr's doorstep.

*"Margrethe:* Why did he come? What was he trying to tell you?

*Bohr:* He did explain later.

*Margrethe:* He explained over and over again. Each time he explained it became more obscure....I've never seen you as angry with anyone as you were with Heisenberg that night.

*Heisenberg:* Now we're all dead and gone, yes, and there are only two things the world remembers about me. One is the uncertainty principle, and the other is my mysterious visit to Niels Bohr in Copenhagen in 1941. Everyone understands uncertainty. Or thinks he does. No one understands my trip to Copenhagen."

I was not surprised that Frayn won Broadway's coveted Tony Award for the best play of the year 2000. And like many scientists, I hope that a piece for the theater may create interest among some of the public in Bohr's and Heisenberg's science—although for most viewers, the discussion on the stage is often so elusive and mysterious that, in the words of a reviewer,<sup>1</sup> "'Copenhagen' makes you feel smarter for having seen it...even if you don't really understand it."

But by mixing in one work the three quite different worlds of science, history, and theater, it is highly likely that much of the audience will confuse the play—a work of fiction—with an historical documentary. So many think they

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<sup>1</sup> *New York Times*, June 2, 2000, p. B6.

know all about Mary Stuart or J. Robert Oppenheimer from having read or seen the dramas using those names in the titles. They tend to forget that the task of the poet and dramatist is, as Samuel Taylor Coleridge put it in his *Biographia Literaria* of 1817, to create in the reader or viewer the “willing suspension of disbelief” and “poetic faith.” John Keats, at about the same time, also memorably celebrated what he called the “Negative Capabilities” of great authors, which he defined as their ability to remain “content with half knowledge.”<sup>2</sup>

### **Jungk, Powers, and the Start of a Legend**

These truths are especially relevant for the case at hand; for Frayn had based his play—as he was writing it originally for publication in Great Britain in 1998—on two deeply flawed publications by journalists. The first is Robert Jungk’s book, *Brighter than a Thousand Suns: A Personal History of the Atomic Scientists* (NY: Harcourt Brace & Co., 1958, based on his German edition of 1956). In it, Jungk published the most familiar version Heisenberg himself gave of what in Frayn’s play becomes the key event—the private conversation between Heisenberg and Bohr during that evening in 1941, which Bohr ended abruptly, disturbed by something Heisenberg had said.

Heisenberg’s own account offered to Jungk came in his four-page letter of 18 January 1957, responding to Jungk’s request for it of 29 December 1956. Heisenberg’s account, which Jungk published only in part, asserted that in 1941 the researchers in Heisenberg’s “*Uranverein*”—the organization of German scientists assembled soon after the outbreak of WWII to put nuclear physics to use in the war effort of the *Reich*—“knew that fundamentally one could produce atom bombs, but we estimated the necessary technical expenditure as larger than

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<sup>2</sup> Lionel Trilling, *The Selected Letters of John Keats* (NY: Farrar, Straus and Young, Inc., 1958), p.28).

it was then in fact" (my translation, from Heisenberg's German original). Still, Heisenberg contended, physicists engaged in such work could have "decisive influence on further developments, since they could argue that by means of extreme effort it would perhaps be possible after all to put them into play." And his discussion with Bohr, Heisenberg noted, "probably started with a question I raised in passing whether it was right for physicists to devote themselves in wartime to the uranium problem..." Heisenberg observed that Bohr "understood at once the implication of this question" and was shocked ("*erschrocken*") by this train of thought, assuming "that I had intended to convey to him that Germany had made great progress in the direction of manufacturing atomic weapons." Heisenberg added he was unable to "correct this false reaction."<sup>3</sup>

There are significant parts of Heisenberg's letter to Jungk which Jungk chose not to print, and which, as far as I know, strangely seem not to have been made public. For example, in his immediate next sentence Heisenberg reported he told Bohr of the "moral consideration" of making atomic weapons. Heisenberg had raised the same theme in a previous letter to Jungk (17 November 1956). In it Heisenberg confessed to have suppressed any memory of an earlier discussion about atomic weapons; "perhaps out of fear it was pushed away inside" ("*vielleicht aus Angst innerlich verdrängt*"), and Heisenberg elaborated on his curious experience of *Verdrängung*.

To be sure, even in the parts of his letter which Jungk did publish, Heisenberg had been careful to warn at the beginning about the uncertainty of his memory, writing, "In my memory, which naturally after such a long time

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<sup>3</sup> Quoted (in my translation) from Robert Jungk, *Heller als tausend Sonnen: Das Schicksal der Atomforscher* (Munich: Wilhelm Heyns Verlag, 1990; pp. 399-401). The letter was rather freely translated in Jungk's English-language edition, mentioned above.

may deceive me....” He also introduced the most controversial part of his recollection of the encounter with Bohr with the words “The conversation may have begun...” Nevertheless, Heisenberg’s account, together with Jungk’s report in his widely read book on his own conversations and correspondence with other German nuclear scientists, provided the key suggestion which Frayn’s play vastly expanded: that at least for Heisenberg, *an impending moral compunction may have existed about his working towards an atomic bomb.*

This was not the first time this idea had been launched. It had surfaced on August 7, 1945, in a remark by C. F. von Weizsäcker to Heisenberg and the other German scientists who were then being detained in England at Farm Hall, with their conversations secretly recorded by their captors. Immediately after those scientists had read and heard about the existence and use of the atomic bomb on the part of the Allies, von Weizsäcker proposed: "History will record that...the peaceful development of the uranium engine [reactor] was made by the Germans under the Hitler regime, whereas the Americans and the English developed this ghastly weapon of war."<sup>4</sup> (To his credit, in 1988, in his revealing autobiographical memoir, he confessed at last that the "Uranverein" scientists had been hoping to build a bomb.<sup>5</sup> And to Otto Hahn’s credit, at Farm Hall he responded to von Weizsäcker at once: “I don’t believe that” — which nobody else there contradicted.)

Max von Laue was present at the time, having strangely been made part of the group of internees, although this distinguished physicist had been an

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<sup>4</sup>For the reports on the conversations and detailed commentaries, see Jeremy Bernstein, *Hitler’s Uranium Club: The Secret Recordings at Farm Hall*. The scientist’s quoted passage appears on p. 138 of the book’s paperback edition (New York: Copernicus Books, 2001).

<sup>5</sup> Carl Friedrich von Weizsäcker, *Bewusstseinswandel* (Carl Hanser Verlag, 1988), pp. 362-383. On p. 365, a *Stern* interviewer asks the author: "Die Idee war also: Wir wollen die Bombe bauen, damit wir etwas in der Hand haben? C. F. v. W.: Ja. Oder mindestens, wir wollen so nahe an die Bombe herankommen, wie wir eben können." ("So the idea was: We want to build the bomb, to have something in hand?" C. V. v. W.: "Yes. Or at least, we want to come as close to the bomb as we could.")

outspoken opponent of the Nazi regime throughout and had not been engaged in atomic energy research. In a later letter, von Laue recorded his observation that right then and there, at those August 1945 conversations (*Tisch-Gespräche*), a *Lesart* (a version) of history was fashioned: the German failure to produce a bomb was not chiefly due to the numerous errors<sup>6</sup> made during their research, together with insufficient help obtained from their administrators and the ultimate disillusion of the latter with the whole project. Also, it was not, as now most agree, that compared to the Allies the German researchers had a relative “lack of zeal” about their work. For one of the major mistakes the German scientists had made was to understand the likelihood of the other side to have the skill and wits to pursue the bomb project successfully. For example, hearing on August 6, 1945 on the radio about the first atomic bomb, they felt at first it was a hoax, a chemical explosion, with Heisenberg saying, according to the Farm Hall Papers, “All I can suggest is that some dilettante in America who knows very little about it has bluffed them....<sup>7</sup> Rather, that failure was now to be traced conveniently either to the unrealistic timetable for achieving it, or, as von Laue heard it from Weizsäcker, “because they simply did not want to have it all” [*“weil sie überhaupt nicht wollten”*]. This last phrase again underlined the

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<sup>6</sup>See for example Bernstein's book. (Max von Laue's letter is reprinted there, in Appendix B.) The book is an excellent source for understanding the ambitions of Heisenberg's “*Uranverein*,” and the many reasons for its ultimate lack of success during more than five years of work to design and build even one functioning reactor. Also see David Cassidy's article “A historical perspective on Copenhagen,” *Physics Today* 53, 7 (2000): 28-32, accessible via the Internet under <http://www.aip.org/pt/vol-53/iss-7/p28.html>, and Rudolf E. Peierls, *Atomic Histories* (Woodbury, NY: American Institute of Physics, and New York: Springer Verlag-New York, 1996), pp. 108-116. Peierls analyses some of the decisive errors made during the German nuclear program. Heisenberg himself, in an interview with J. J. Emerec (29 August 1967), somewhat harshly criticized a crucial “error” Walther Bothe had made in “a measurement of the neutron absorption coefficient of pure carbon,”—a crucial measurement, but one that Heisenberg said had not been checked by repetition.

<sup>7</sup> Bernstein, *Uranium Club* (see Footnote 3, p. 116). On several of these points, there are also two other relevant sources: Jonathan Logan, “A Strange New Quantum Ethics,” *American Scientist* 88 (July–August 2000), pp. 356-359, and Abraham Pais, “What Happened at Copenhagen?,” *Hudson Review* (Summer 2000), pp. 182-189.

suggestion of a moral reluctance to do such work, in contrast with the eagerness of the Allies.

That story of a supposed moral contrast between the opposing sides was later elaborated by some German scientists, and undoubtedly helped them at home to explain to the public their failure during nearly six years of work on the project. In addition, the same story also was given a prominent place in Robert Jungk's book because it fitted perfectly Jungk's own agenda at the time, which he had frankly revealed in his first chapter, entitled "How the book came to be," as published in his German edition. Indeed, Jungk's letters show that he was at first almost grotesquely grateful for his "coup." But eventually he came to understand that he had been gravely misled--even, as he put it, "*verraten*," betrayed, having been used to propagate "*eine Legende*."<sup>8</sup>

The legend might eventually have blown away for lack of credible evidence. But it was given new, vigorous life by the widely distributed publications of a second journalist, Thomas Powers. In his book *Heisenberg's War* and his many articles on the same topic, Powers took the tale of moral compunction to its logical extreme: Now Heisenberg's failure as a leader of the "*Uranverein*" during the war years was portrayed as essentially an act of *conscious sabotage*<sup>9</sup>: Heisenberg was portrayed as fully understanding what had to be done, but keeping it secret, misleading all his co-workers throughout, "giving a different estimate for critical mass to different people,"<sup>10</sup> and effectively subverting the Germans' path to developing an atomic weapon. As Powers put it: "Heisenberg did not simply withhold himself, stand aside, let the project die.

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<sup>8</sup>For a detailed presentation, see Robert Jungk's autobiography, *Trotzdem: Mein Leben für die Zukunft* (Munich: Carl Hanser Verlag, 1993), pp. 297-300.

<sup>9</sup> Thomas Powers says he never used the word "sabotaged." He prefers the circumlocution that Heisenberg "found a way of leading it [the bomb project] into a closet where it languished for the remainder of the war...." (*The New York Review of Books*, April 11, 2002, p. 85.)

<sup>10</sup> *Ibid.*



He killed it."<sup>11</sup> To this day, this and similar versions are being energetically defended by a few, even though Powers has acknowledged that he has not convinced any historians.

But that brings us back to the play "Copenhagen," because Frayn revealed in the original "Postscript" (Postscript I, 1998), printed in the first edition of his published text, that it was Powers' "extraordinary and encyclopaedic" book which "first aroused my interest in the trip to Copenhagen."<sup>12</sup>

The play skillfully prepares the audience for the moving climax near the end: Heisenberg accuses Bohr of having gone to Los Alamos, upon which Bohr is made to add: "To play my small but helpful part in the deaths of a hundred thousand people," whereas Heisenberg "never contributed to the death of one single solitary person." At this, Frayn's Heisenberg exults: "There'd be a place in heaven for me," implying that Bohr belongs to the other place. That sentiment is immediately reinforced by Heisenberg's final bravura soliloquy in which Heisenberg bemoans what the ferocious Allies (without provocation?) had done to his beloved homeland during the war.

As the audience was leaving the performance in New York at its premier in the U.S.A. in Spring 2000, I saw tears in many eyes. At least for those persons, all "uncertainties" had given way to a "knowledge" of what really had happened on that day in September 1941, and to which side the moral victory belonged.

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<sup>11</sup> Thomas Powers, *Heisenberg's War: The Secret History of the German Bomb* (New York: Knopf, 1993), p. 479. For typical, authoritative presentations of the assumptions and errors in Powers' book, see the book review in *American Historical Review* (December 1994, pp. 1715-1718), and Peierls' book.

<sup>12</sup>Michael Frayn, *Copenhagen* (London: Methuen Drama, 1998), p. 100; a second edition with a few changes but a completely revised Postscript was published in 2000 (New York: Anchor Books). That revised Postscript ["Postscript II"] is available on the Internet (<http://web.gsuc.cuny.edu/ashp/nml/copenhagen>). Post-postscript (Postscript III) was circulated at a meeting in Washington, April 2002. Significantly, for understanding the play, Frayn confesses in "Postscript II" that when he wrote the play he had not yet read either David Cassidy's biography of Heisenberg nor Jeremy Bernstein's, both of which he now praised.

The triumph of good fiction was palpable, and even made plausible the implication that it correctly presented the actual historical events as well.

### **Bohr's Refutation of the Legend**

But as to historical facts, the account of the famous meeting in September 1941, as offered by the actual Heisenberg and Jungk, presents only one side. At the time of the New York performance, Bohr's own reaction in writing was still kept secret. Only since February 2002, has it been freely accessible to all (see [www.nba.nbi.dk](http://www.nba.nbi.dk)). But as it happened, in 1958, I was in Copenhagen at a meeting in honor of Niels Bohr's memory. There I was approached by Bohr's son, Erik Bohr, probably because I had been involved with organizing several archives of scientists, including Einstein's. He showed me an unsent letter which he explained had been written by his father but found after Bohr's death, folded into Bohr's copy of the book by Jungk. That striking letter (the first, longest, and most important of the documents released later), addressed to Heisenberg, is, as intended, a powerful corrective to previous stories disseminated by Heisenberg, Jungk and others. It takes serious issue with every detail of Heisenberg's published version of the 1941 meeting, in quite firm language--so firm that this may have been one of the reasons why Niels Bohr had apparently decided not to mail it.

When asked what should be done with the document, I advised that it be preserved and put into the Niels Bohr archives. Today that letter is there, together with the ten other drafts of it. Although the letter had not yet been embargoed by Bohr's family when it was shown to me, I thought it would have been inappropriate for me to say more about it until it was released. So, unless Bohr's family had decided otherwise, the world would have remained for many years with half-knowledge about what happened during that walk in 1941.

Now that Bohr's letter drafts to Heisenberg are available freely on the Internet, every interested reader should take advantage of a rewarding exercise: putting the portion of Heisenberg's letter as published in Robert Jungk's book next to a printout of those fascinating drafts by Niels Bohr. As Bohr intended them, his documents illuminate that meeting with Heisenberg in 1941, and show how incomplete and even erroneous previous accounts were. They also allow us again to see Bohr's mind at work: He typically goes again and again over the same ground in successive drafts, bringing in new details--as he did when dictating his physics papers.

Bohr's documents also remind us that Heisenberg had come to Denmark with his colleague von Weizsäcker, that they had also spoken with others there, and that those encounters in 1941 were also not successful. Thus one of Bohr's drafts records: "During conversations with Møller [the Danish physicist], Heisenberg and Weizsäcker sought to explain that the attitude of the Danish people toward Germany, and that of the Danish physicists in particular, was unreasonable and indefensible since a German victory was already guaranteed and that any resistance against cooperation could only bring disaster to Denmark."

Turning to Bohr's first and most interesting document, it starts by offering Heisenberg the opportunity for excusing himself, by suggesting that Heisenberg's memory might have greatly deceived him when he wrote to Jungk. And in fact, as noted above, Heisenberg had started that letter with the disclaimer: "As far as I remember, although I may be wrong after such a long time...." And later Heisenberg had used the word "probably" when trying to describe how his talk with Bohr started; and later still: "I may have replied...." In stark contrast, Bohr writes at the beginning: "Personally, I remember every word of our conversations."

Bohr's first document then recounts that Heisenberg freely offered Bohr the astounding confession in September 1941 that he was "completely familiar with them [atomic weapons] and had spent the past two years working more or less exclusively in such preparation." Bohr explains his reaction: Not anger, as some insist who want to paint him as an angry old man, but the shock of *fear*. After all, the prospect Heisenberg offered him was that of a successful and energetic pursuit by the German team to make an atomic bomb, at the very time when Hitler's armies were making their greatest advances. That ghastly prospect was, as Bohr wrote there, "a great matter for mankind."

Even at that point, Bohr, to whom Heisenberg had been, during their long and fruitful scientific collaboration in the 1920s and early 1930s, a kind of successful son, again gently suggests to Heisenberg a way out. Bohr writes that reporting to Jungk his having been shocked by the idea that atomic weapons were possible in principle was a "misunderstanding...due to the great tension in your mind." What Bohr called his "shock" was, he writes, that "as I had to understand it, ... Germany was participating vigorously in a race to be the first with atomic weapons." To make sure Heisenberg understood properly, Bohr then repeats that his own memory of the conversation was clear. That is entirely plausible: the crucial discussion between Heisenberg and himself had been very brief; the topic raised by Heisenberg was immensely important; and afterwards Bohr reported on the conversation, in "thorough discussion" with others, including members of his Institute, and "other trusted friends in Denmark." Not much later, Bohr, having been spirited out of occupied Denmark, spoke with members of the British intelligence who de-briefed him.

In some of the last drafts, Bohr repeats that he "carefully fixed in [his] mind" every word that was uttered when he and Heisenberg met on that ominous occasion. Therefore he finds it "incomprehensible" that Heisenberg

should have claimed later he had "hinted" that the German scientists "do all they could to prevent such an application of atomic science." That spin of supposed moral qualms has of course been at the center of revisionist writings.

There is much to ponder here. But, in short, when comparing Heisenberg's letter and Bohr's documents, we see that Bohr contradicts and tries to correct every major point in Heisenberg's published account. In fact, one may speculate that Bohr in the end did not send off his letter to Heisenberg, on which he had worked for so long, because even the (to us) relatively mild words in his documents seemed to him to be uncharacteristically strong. And it is yet another irony that Bohr, who had no reason to hide or misremember anything, eventually did not mail his letter, whereas Heisenberg did let Jungk publish his account, even though when he did so he had good reasons for a *Verdrängung*, and for misremembering.

### **The Playwright as Moral Arbiter**

A natural question raises itself. What can be done about the text of the play, written in 1998, based in part on Powers' untenable main contention, that Heisenberg knew how to make a workable bomb, but kept the knowledge to himself? Frayn confessed in his second Postscript of 2000 that by then he had read David Cassidy's "excellent biography" of Heisenberg, and at last understood also the German scientists' Farm Hall conversations, thanks to Bernstein's commentary. Thus, he now dismissed Powers' main thesis with the cutting comment, "If he [Heisenberg] had kept the fatal knowledge...from anyone, as Powers argues, then it was from himself." Worse yet, now that we know from Bohr's documents and von Weizsäcker's own acknowledgment of Germany's project to try to build an atomic bomb, what should the author of the play now do about such passages in which his Heisenberg remarks dramatically: "I understood very clearly. I simply didn't tell the others"? And later, "I was not

trying to build a bomb." Perhaps the actor will be instructed to deliver such lines with heavy irony.

Frayn did make some minor changes and corrections for the play's revised version of 2000, mostly cleaning up small errors in the physics and acknowledging other scientists' contributions. But even though it is now acknowledged to be even further from historical reality, the body of the play must of course stand. After all, it remains a hugely successful work of *fiction* for the theater, honored with awards, no matter that a very different story is known about the actual meeting in 1941.

Moreover, the ever-pregnant Muse of History may well have surprises in store for us, in days and years to come. New documents are bound to appear, perhaps details about the slave laborers who had to process the uranium for Heisenberg's "Uranium Club." Such findings may keep historians busy, but surely should not require Michael Frayn to issue yet more postscripts--as long as he sees his role to be a writer of fiction and not also of a factual documentary, even of one that has a moral message.

Yet, there are signs that he has chosen to step out of the role of a playwright, and reveal himself as a moral arbiter between the actual persons involved, rather than only between actors on a stage. He spoke more recently of the audience drawing "its own moral conclusions." And in an interview, published in the *New York Times* (9 Feb. 2002), he goes further, and concludes: "Heisenberg didn't in fact kill anyone....," whereas Bohr "did actually contribute to the death of many people...."--referring respectively to one person who in fact had been working for many years, with varying degrees of enthusiasm, for Germany's war machine, and to the other who had to flee for his life from Denmark and came late to Los Alamos, where his principal activity was to develop post-war arms control policies.

In this double role the playwright seems sadly to forget that his thing's a *play*. That should be enough. Other plays, imagined on the more or less vague semblance to historic events, from Shakespeare's *Richard III* to Brecht's *Galileo*, have survived well and retain their authenticity, despite their grave dissonances with respect to historians' analyses of the actual cases. Let me quote John Keats again. He advised that authors of fiction should be "capable of being in uncertainties, mysteries, doubts, without any irritable reaching after facts and reason."

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