

# The Copenhagen Interpretation: Exploring Science on Stage

Michael Frayn's play *Copenhagen*, which opened in London in 1998, in New York in 2000, and finally made it to Los Angeles in late 2001, explores what might have been said during a 1941 meeting of Niels Bohr and Werner Heisenberg at Bohr's home in the German-occupied capital city of Denmark. Although in the end all the ambiguities and "uncertainties" remain, the three characters (including Bohr's wife, Margrethe), with the knowledge of hindsight "when all are dead and gone," reenact various drafts of the purpose of Heisenberg's visit—and the ultimate question of why Heisenberg did not build an atomic bomb for the Nazis.

Caltech interest in the play naturally ran quite high, and on December 10, in a packed Beckman Auditorium, Caltech hosted a panel, "The Copenhagen Interpretation," convened "to consider the broader scientific, historical, philosophical, and artistic dimensions of this encounter and its dramatization." The panel was moderated by Steve Koonin, provost and professor of theoretical physics, who, in some non-Caltech aspects of his professional life, also is involved with "nuclear weapons and the scientists who are concerned with them." Emphasizing that there was no script for the evening—"think jazz performance rather than chamber ensemble"—Koonin introduced the rest of the panel: Bob Christy, Institute Professor of Theoretical Physics, Emeritus, who had worked on the Manhattan Project

and was known for his experimental, as well as theoretical, work; Diana Barkan Buchwald, associate professor of history, and general editor and director of the Einstein Papers Project; Hank Stratton, who plays Werner Heisenberg in the Los Angeles production of the play; Marge Leighton, a close friend of the Bohr family (and widow twice-over of Caltech physics professors Tommy Lauritsen and Bob Leighton); and Jay Labinger, administrator of the Beckman Institute, who often writes on the historical, cultural, social, and literary aspects of science (see his review of two other science plays in *E&S*, 2001, no. 1).

After Hank Stratton described the play briefly (but told the audience they'd have to "spend 55 bucks" to get the rest of it), Diana Barkan Buchwald, a historian of science, outlined what was going on in physics at the time: fission had been discovered in Berlin in 1938 by Lise Meitner, Otto Hahn, and Fritz Strassmann. Bohr brought the news to America in 1939, she said, but by 1940 the Germans were increasingly isolated, and

**In the Los Angeles production of Michael Frayn's *Copenhagen* at the Wilshire Theatre, Len Cariou (right) appeared as Niels Bohr, Mariette Hartley as Margrethe Bohr, and Hank Stratton as Werner Heisenberg.**



**At the Nuclear Physics Congress in Rome, 1931; from left: Robert A. Millikan, Marie Curie, and Werner Heisenberg. Ten years later, the international physics community would no longer be sharing research on nuclear physics.**



Allied scientists, in a self-imposed embargo, stopped publishing any work on fission. “By 1939 both sides were planning to use fission either for a bomb or for a reactor or both.” Einstein wrote his famous warning letter to President Roosevelt in August 1939 (see *E&S*, 2000, no. 3), urging him to make contact with Enrico Fermi and Leo Szilard, who were working on chain reactions. Buchwald placed the birth of the Manhattan Project at the end of 1941, when James Conant convinced the government that a bomb had to be built.

Bob Christy recalled being a grad student at Berkeley in the spring of 1939: “I remember the excitement of the news of fission and how every week a new experiment verifying this was being done and reported. It was an exceedingly exciting time.” But by the time Christy joined the Manhattan Project in Chicago in 1942, the pure excitement had given way to urgent determination. Many of the project’s senior scientists, he said, who had been forced out of Europe and had personal recollections of the Hitler regime, “were deeply concerned about the possibility that Hitler would develop a bomb before it was accomplished elsewhere.”

Getting back to the actual characters in the play, one of the “complementarities” in the play, said Koonin, “is between the slow-moving but very deep Niels Bohr, who does his papers over many times until he gets to perfection, and the more mercurial Heisenberg, who shoots from the hip and is usually pretty accurate.” How accurately are they portrayed? Marge Leighton and her husband, Tommy Lauritsen, went to Copenhagen in 1952–53 and spent much time with the Bohr family, who “treated Tommy as another son.” She described Bohr as “so soft-spoken you could barely hear him. . . . I wanted to hear everything he had to say, so I was practically sitting on his lap in order to hear him.” (Obviously such low volume wouldn’t work on stage.) Bohr talked more about artists and writers than scientists, she said; he was

a great admirer of Mark Twain. When she saw the London production, she was shocked at the portrayal of Margrethe Bohr as “shrill and confrontational,” rather than the gracious person she remembered. Mariette Hartley, who plays Margrethe in the Los Angeles production, is better, said Leighton.

The discussion of dramatic license brought the panel to a particular line (which Stratton could, of course, deliver on command) near the end of the first act—when Heisenberg confronts Bohr about Bohr’s participation in the Manhattan Project. When Bohr says Robert Oppenheimer tormented himself after the bomb, Heisenberg replies: “Afterwards, yes. At least *we* tormented ourselves a little beforehand. Did a single one of them stop to think, even for one brief moment, what they were doing?”

That line comes from Heisenberg’s postwar recollections, said Buchwald, who claimed it reveals Heisenberg’s self-righteousness, which many consider unwarranted. Someone who had been, at the very least, an active participant in German war preparation has no right to be asking that sort of question, she said, and it’s also in hindsight; there’s no evidence of what Heisenberg actually thought at the time. And furthermore, Buchwald insisted, “scientists in the United States and England *did* stop to think about what they were doing.”

Christy confirmed that “it was certainly a major preoccupation of Bohr himself. . . . I know that during his visits to Los Alamos, he and Oppenheimer had lengthy discussions on the question of international control and how to deal with this new phenomenon they were beginning to produce.”

It was pointed out that Lise Meitner, who fled from Germany to Sweden, refused to come work on the Manhattan Project. On the other hand, said Christy, Meitner’s nephew, Otto Frisch, and Rudolf Peierls, both refugees in England, first

PICTURE CREDITS: 52, 54 – Joan Marcus; 53, 55, 56 – Caltech Archives



**The Bohrs and Heisenberg  
duke it out on stage.  
Danny Kaye singing  
“Thumbellina” it’s not.**

showed that building a bomb was feasible. Interestingly, Frisch and Peierls were listed as enemy aliens, added Buchwald, and “excluded from officially working on what was called the Tube Alloys Project, the English precursor of the Manhattan Project.” They were, instead, assigned to work on radar, “which they didn’t know very much about, but they continued to work on fission on their own.”

Returning to Heisenberg’s line about morality, which has caused much controversy among scientists and historians, Stratton (who insisted he wasn’t just trying to defend his character) argued that the controversy it has provoked is all the more reason to keep the line in the drama and not ignore it. “It sparks a debate.”

This led to the subject of science as drama. “Science can certainly be good drama,” said Jay Labinger, “but it presents problems.” Like Leighton, Labinger had first seen the London production and told the story of walking into the theater ahead of a couple of Americans, one of whom said to the other, “I’m not so sure this *is* a musical, you know.” He wondered throughout the play how the science was going over with “people who were expecting to hear Danny Kaye sing ‘Thumbellina.’”

“If you want to communicate scientific concepts,” said Labinger, “you tend to fall back on dialog like, ‘You remember how we discovered this, and so-and-so taught us that?’ I think the first half of the second act dies a little bit when there’s too much of that. But to a large extent this play somehow avoids that. Part of it is that the scientific content isn’t essential to the play. You can get a lot out of it and miss all the science. It’s enriching, certainly, and the more you get, the better, but it’s not central.”

“But certainly in the present play,” commented Koonin, “understanding something about the uncertainty principle and complementarity—all the things that go into the Copenhagen interpreta-

tion of quantum mechanics—makes Frayn’s construction look that much more clever.” He compared Labinger’s view with watching *The Simpsons* on TV: “You can watch it at the level of your kids” or enjoy it at another level.

Discussion then turned to the question of just how difficult it was to construct a nuclear device, and why it was such a daunting task at the time. “How can it be that the Germans really got it so wrong, when in retrospect the physics is pretty simple?” asked Koonin. What was so daunting was the separation of the uranium isotopes, replied Christy. The Germans thought it was impossible and just gave up, but Christy knew of at least five projects in this country that were exploring this before the Manhattan Project got under way. The Americans were also pursuing the production of plutonium from a reactor as an alternative to  $U^{235}$ , Christy said. But the Germans “hadn’t done anything to plan a real production effort,” even though they had already, before Heisenberg’s meeting with Bohr, demonstrated that “a sub-critical reactor of their design would multiply neutrons and therefore showed the way to making a full-size reactor that would produce plutonium.” “So what was different?” asked Koonin. “Why did the Americans pursue this so vigorously, and the Germans seem to have done it in a rather desultory manner?”

Physics was done differently in this country, said Christy, who described Ernest Lawrence’s cyclotron operation at Berkeley as the beginning of Big Science. “He made a big machine. The nuclear physics was kind of a sideline with him; he had lots of people there working with him who did the nuclear physics because he had the machine.” It was the combination at Berkeley that was so important—the experimental physicists, the theoretical physicists, the engineers, and the chemists working as a team, attending seminars, and talking with one another. There was a similar kind of teamwork at Caltech, said Christy, but on a smaller scale. “Tommy Lauritsen’s father, Charlie, had an accelerator program here. Oppenheimer was a close friend of Charlie Lauritsen and also of Ernest Lawrence. The combination of the theoretical and experimental physics and the engineering was the way physics was done in many institutions in this country.” Tommy Lauritsen went to Copenhagen in 1939 and started work on an accelerator there, added Leighton, but left when the Germans occupied the country.

The structure of science was different in Germany, said Buchwald; theoreticians and experimentalists didn’t often meet. “The received view among historians about the failure of the German atomic project has been that Heisenberg wasn’t a good enough plumber. He wasn’t good with his hands. He was a theoretician who didn’t know how to put together a big group, how to collaborate with technicians and engineers.”

“And yet Germany, and more generally Western Europe, was the right atmosphere to create this marvelous science of quantum mechanics,” said Koonin, “A great community of people working together, but in a theoretical way more than in an experimental way.”

There was some discussion about how much science Heisenberg did after the war. Not much, everyone seemed to agree. Koonin heard him give a seminar at MIT in the early '70s, and Christy remembered a seminar he gave at Caltech on some field theory that was way out of the mainstream. Leighton also remembered meeting Heisenberg at Caltech after the war and said that Tommy gave him a pretty rough time about his war activities. Buchwald added that although Heisenberg became very important in postwar Germany—he held several high positions and was a leader of the scientific community—he was always very concerned about his war reputation. Bohr was actually very generous with Heisenberg after the war, she said, and they met at international meetings. But he was badly received in this country. “There are anecdotes about meetings in the United States in the first years after the war, about people walking around with a drink in one hand and a notebook in the other, so they wouldn’t have to shake Heisenberg’s hand,” said Buchwald.

Stratton rose to the defense of his man, whose skin he has to inhabit eight times a week. “I think he’s the most complex character in the play. . . . I have a deep compassion for him but also have huge personal problems with his actions, as

The combination of the theoretical and experimental physics and the engineering was the way physics was done in many institutions in this country. —Bob Christy

From left: Tommy Lauritsen, Max Delbrück, Niels Bohr, and Paul Epstein on the Caltech campus in June 1959.



I’m sure the international scientific and historical community does as well. But that’s all the more reason to expose them in theater,” said Stratton. Buchwald then mentioned the long tradition of plays about science and noted in particular Brecht’s *The Life of Galileo* and Dürrenmatt’s *The Physicists*, both of which were written in the aftermath of World War II and dealt with scientists’ responsibility and guilt.

In closing, Koonin posed a single question for each panelist à la the McLaughlin Group. “Central to the play are the many interpretations of the meeting between Bohr and Heisenberg. What did Heisenberg come to ask or to tell his mentor and collaborator, Niels Bohr? The play goes through the scene at least three times, offering different explanations each time around. So what do you think Heisenberg said to Bohr at the 1941 meeting? Was it the question about morals that’s in the play? Did Heisenberg try to pump Bohr for information about the Allied program? Did he tell him that he was sabotaging the German effort? Did he ask Bohr to make a pact mutually renouncing nuclear weapons work? What do you think?” (The answer may come out soon when the Bohr family releases an unsent letter to Heisenberg.)

It occurred to Christy that Germany lacked a cyclotron, which was necessary for learning how to deal with plutonium. And Bohr had one for his neutron experiments. “So my thought is that maybe he went there to secure the cooperation of the Bohr Institute in studying various problems with their cyclotron.” He qualified this by saying he wasn’t sure he believed it, though.

Labinger changed the question: (“Punt!” called Koonin.) “Will it make any difference at all to our response once we have this answer? What if, after the letter, it turns out that actually they never met at all, but they agreed to tell the story so Heisenberg would get his travel expenses reimbursed or something like that. I just don’t see how that’s going to influence what we think about

the *play*, which is an exploration of alternative possibilities.”

“It depends on where you’re sitting and what you observe,” said Leighton. “You’re not being dishonest; you’re just bringing what you have to it. And the scientists observing it—what they think happened depends on what they’re bringing to it.”

Buchwald agreed up to a point. “The play tries to tell us that history is uncertain. I completely agree that what goes on in the hearts of men in difficult times when they meet and talk may, even a year or two later, change or be very uncertain. But there are other aspects of this encounter that are not so uncertain. We know that Bohr got very angry, and so most of us suspect that Heisenberg was trying to pump him for some sort of information.” She pointed out that other German physicists, such as Max von Laue and Max Planck, wrote at the time about how they felt about the war, “whereas everything we know about how Heisenberg *felt*, we know only from his retrospection. Everything we know about what he *did*, we know from the historical record. So the ambiguity should be allowed, but, I think, only so far.”

Koonin closed with his own prediction: “I think Heisenberg was trying to gain some advantage for Germany, either by asking Bohr to cooperate with the German nuclear effort or by asking him to forego working on the Allied effort.” Koonin thought Heisenberg had figured out that building a bomb was going to be really tough and doubted whether the Germans could pull it off, while fearing that maybe the Allies could. “So he was either trying to get Bohr’s expertise or, more likely, just saying to Bohr, ‘Hey, let’s just not push on this because it’s not going to work anyway.’”

A lively question session followed. The *Copenhagen* panel, including the questions, can be viewed on line at <http://atcaltech.caltech.edu/theater/>. □ —JD

*As the panelists noted, the Bohr family has decided to release (on February 5) a letter Bohr wrote to Heisenberg but never sent. According to an account in The Times of London January 6, the few people who have seen it say the letter reveals that in their 1941 meeting, Heisenberg confided the shocking news that the Germans (and he himself) were working on building an atomic bomb for use in the war. His motive for this confidence is apparently unclear from Bohr’s letter, which he wrote in response to Heisenberg’s claim in a 1958 book that he had always intended to sabotage Hitler’s nuclear effort.*

The play tries to tell us that history is uncertain. I completely agree that what goes on in the hearts of men in difficult times when they meet and talk may even a year or two later change or be very uncertain. But there are other aspects of this encounter that are not so uncertain. —Diana Buchwald

## PLUMBERS

The Americans were good “plumbers,” and the Germans were not. That’s one view to come out of the Caltech *Copenhagen* panel on why the Germans didn’t manage to build an atomic bomb and the Americans did.

Although he was not involved directly in the Manhattan Project, no one exemplifies American (and Caltech’s) superior physics/plumbing collaboration better than Charles Christian Lauritsen. After training as an architect in his native Denmark, Lauritsen emigrated in 1917 and, although never an actual plumber, designed ships in Boston, worked as a professional fisherman in Florida, and produced radio receivers in California. As chief engineer for a radio manufacturer in St. Louis, he was impressed by a lecture given there by Robert A. Millikan. Millikan was equally impressed with Lauritsen and lured him to Caltech in 1926 to design equipment for his experiments on the cold emission of electrons from metals. By 1929 he had earned his doctorate in physics under Millikan, and in 1932, when it was demonstrated that machines could be used to disintegrate nuclei, Lauritsen already had an X-ray lab ready to roll. Out of Lauritsen’s early radiation experiments grew the Kellogg Radiation Laboratory and Caltech’s long history of distinguished research in nuclear physics and astrophysics, including the Nobel Prize-winning work in nucleosynthesis of Willy Fowler, a graduate student of Lauritsen’s.

Accelerators followed the X-ray tubes, and Charlie’s son, Tommy, who earned his PhD at Caltech in 1939 (under his father), was building a Van de Graaff accelerator like its Caltech model for Niels Bohr’s lab when the Germans invaded Denmark in 1940. Charlie Lauritsen died in 1968, Tommy in 1973.

Robert Oppenheimer, who held joint appointments at Caltech and Berkeley during the ’30s, was a good friend of Lauritsen’s, as was another theorist, Richard Tolman. “Many times they sat after lunch in some old weather-beaten wicker chairs in the sun outside the High Voltage Lab discussing the great happenings of the day in physics,” recalled Fowler (*E&S*, March 1982). Fowler went on to say that “Charlie did more than guide our graduate careers. He taught us how to use a lathe, how to bring the mercury back down in the stem of a Macleod gauge by gently tapping without breaking it, how to outgas the vacuum tube after repairing a leak by painting it with shellac, and a million and one other practical things in the nuclear lab of those days.”

Perhaps if Heisenberg had learned a few “practical things” and sat around in the sun talking to men who could build machines, things might have turned out differently.

