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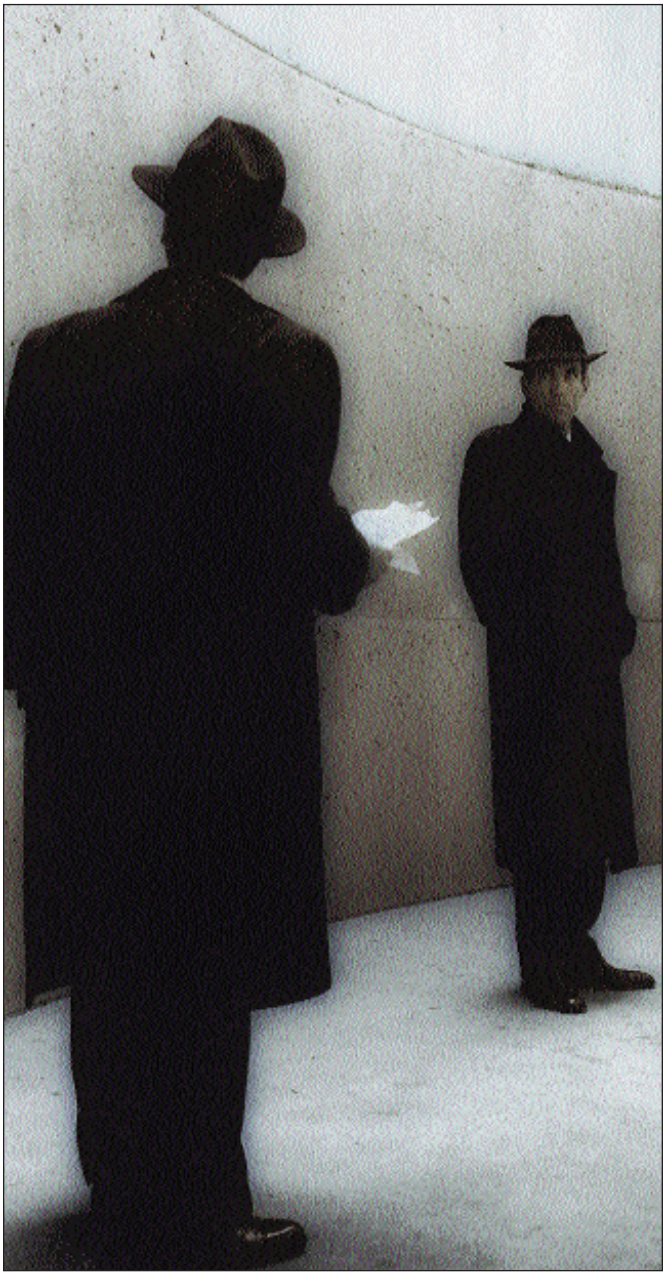

John Hutton • Photo by Gary Isaacs

"HEISENBERG: ------Everyone understands uncertainty. Or thinks he does. No one understands my trip to Copenhagen."

Copenhagen, p. 4

COPENHAGEN

Mar. 12 - May 10 • The Ricketson Theatre

The opposite of a correct statement is a false statement. But the opposite of a profound truth may well be another profound truth.

– Neils Bohr

In 1941 the German physicist Werner Heisenberg paid a strange visit to Copenhagen and the home of his Danish counterpart, Niels Bohr. During the 1920s, these friends and colleagues had revolutionized atomic physics through their work on quantum mechanics and the uncertainty principle. But now the world had changed. Denmark was under German occupation and the two men were on opposite sides in a world war. What drew Heisenberg to the doorstep of Neils and Margrethe Bohr for this clandestine meeting? The private conversation between these two genius physicists has mystified scientists and historians for decades. In Michael Frayn's play, Heisenberg, Bohr and Margrethe meet again, seeking to unlock the secrets of human motivation as they had once worked out the internal functioning in the atom.

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BIOGRAPHY OF THE PLAYWRIGHT

Michael FRAYN

Dramatist, columnist, reporter and translator Michael Frayn was born in the suburbs of London on September 8, 1933. He attended a private school until age 12 when his mother passed away. At this point, his father, a rep for an asbestos and roofing materials firm, placed him in the less expensive public school. He thrived there, displaying a talent for music and poetry and by his teenage years he'd decided to become a writer.

He served in the army as a Russian interpreter and after his discharge, attended the University of Cambridge. Graduating in 1957 with a degree in moral sciences, he soon began working as a reporter and columnist for *The Guardian* (1959-1962) and *The Observer* (1962-1968). With satirical style, his humorous essays were often steeped in the politics and philosophy that would later fill his plays. It was during this time that he published several collections of his columns and essays and wrote novels including *The Tin Man* (1965), *The Russian Interpreter* (1966) and *A Very Private Life (*1968).

The great challenge facing the storyteller and the historian alike is to get inside people's heads, to stand where they stood and see the world as they saw it, to make some informed estimate of their motives and intentions.---- Even when all the external evidence has been mastered, the only way into the protagonists' heads is through the imagination----

Michael Frayn,
from *Postscript* in the Methuen edition

His first play was rejected by the producer of an evening of one acts and in retaliation he wrote *The Two of Us* (1970), a series of four short plays played by a pair of actors portraying two different characters in each play. Though it starred Vanessa Redgrave and Richard Briars, the production was a disaster. He was scathed by the critics and spat upon by audience members as they left the show's premiere. Frayn, however, was undaunted and his future efforts were much more successful.

His 1975 hit, *Alphabetical Order,* received critical praise, winning Frayn the Evening Standard Award for Best Comedy of the Year; a story of a chaotic newspaper office that suffers identity loss when order is imposed. Successes followed with *Clouds* (1976), *Donkey's Years* (1977) and *Make or Break* (1980), another Evening Standard Award winner. It was *Noises Off* (1980), the frenetic glimpse of backstage life, that brought Michael Frayn to the forefront of American theatre. Anything that can go wrong does go wrong in this hysterical farce-within-a-farce. Frayn follows an English theatrical troupe from dress rehearsal to opening night to the closing performance of the typically British sex romp *Nothing On. Noises Off* won him a third Evening Standard Award for Best Comedy of the Year, played London's West End for four years, and, when it opened on Broadway in 1984, received four Tony nominations, including Best Play. A recent London production lead to its Broadway revival in 2001, winning a Tony for Best Supporting Actress and a nomination for Best Revival of a play.

Aside from his comedies, Frayn has had successes with such dramas as *Benefactors* (1984), which dealt with the deterioration of the institution of marriage in the 1960s, and *Copenhagen* (1998), which won him a fourth Evening Standard Award and a 2000 Tony Award®.

Michael Frayn is also known for his translations of several plays by Anton Chekhov, including *The Cherry Orchard, The Three Sisters, Uncle Vanya, The Wood Demon* (renamed *Wild Honey*) and four of Chekhov's one-acts: *The Evils of Tobacco, Swan Song, The Bear* and *The Proposal.*

"[My plays] are about the way we impose our ideas on the world around us."

– Michael Frayn

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NIELS Bohr *Biography*

Life can only be understood backward,
but it must be lived forward.
– Niels Bohr

Niels Henrik David Bohr, one of the most influential scientists of the 20th century and a major force in the field of quantum physics, was born in Copenhagen on October 7, 1885. His father, Christian Bohr, was a well-known Danish physiologist, and his mother, Ellen Adler, was an educator who came from a wealthy Jewish banking family. Their home provided a favorable atmosphere for learning, as his parents encouraged his interest in physics and younger brother Harald's interest in mathematics.

Entering the University of Copenhagen in 1903, he was influenced by Professor C. Christiansen, a profoundly original and talented physicist. After completing his Master's degree in 1909, his interest in physics became more theoretical in nature. Bohr's doctoral dissertation on the explanation of the properties of metals with the aid of the electron theory remains a classic on the subject to this day. It was in this work that Bohr first confronted the implications of Max Planck's theory of radiation.

In the autumn of 1911, he went to Cambridge to follow the experimental work being done by Sir J. J. Thomson and continued to pursue his theoretical studies. By the spring of 1912 he was working in Manchester with Professor Rutherford's laboratory on an intensive inquiry being made into radioactive phenomena. On the basis of Rutherford's discovery of the atomic nucleus, he began to study the structure of atoms. Borrowing from the Quantum Theory as established by Planck, Bohr succeeded in working out and presenting a picture of atomic structure that, with later improvements, still serves as a model of the physical and chemical properties of the elements.

In 1921, Bohr was named director of the new Institute for Theoretical Physics in Copenhagen, which soon became a requisite destination for the world's atomic physicists. It was during a lecture series in Gottingen, Germany, that he befriended the young Werner Heisenberg. In 1933, after the Nazis authorized German universities to fire staff based on their politics and race, he enabled young refugee physicists to come to his institute in Denmark. His research focused on the constitution of the atomic nuclei and their transmutation and disintegration. According to his view, a liquid drop would give a very good picture of the nucleus, and this "liquid droplet theory" promoted the understanding of the mechanism of nuclear fission. The Nobel Prize for Physics was awarded to Niels Bohr in 1922 in recognition of his work on the structure of atoms.

Bohr also helped clarify some of the problems encountered in quantum physics by developing the concept of complementarity. This concept showed how deeply changes in the field of physics have affected fundamental features of our scientific outlook, and how the consequences of this change of attitude reach far beyond the scope of atomic physics and touch upon all domains of human knowledge.

During the Nazi occupation of Denmark, Bohr and his family fled to Sweden and then to America where he worked with the Atomic Energy Project to develop the atomic bomb. As early as 1944, however, his concern about harnessing the power of nuclear energy led him to advocate control of nuclear weapons and world peace through the open sharing of knowledge among nations. He expressed these ideas to Winston Churchill and President Franklin Roosevelt, both of whom rejected his recommendations. After the war, he helped establish the European Center for Nuclear Research (CERN), a group fighting against the proliferation of nuclear arsenals. This cause was also championed by Heisenberg, yet both men remained adversarial in their relationship.

In our description of nature the purpose is not to disclose the real essence of the phenomena, but only to track down, as far as it is possible, relations between the manifold aspects of our experience.
– Niels Bohr. *Atomic Theory and the Description of Nature* (1939)

Bohr remained active and alert until his death in Copenhagen on November 18, 1962 at the age of 77.

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Margrethe BOHR Biography

It is not possible to talk about my father without, at the same time, emphasizing the importance my mother had. Her opinion and judgement were his mainstay in daily life and she shared her life with my father in every possible way.

– Hans Bohr

Margrethe Norlund grew up in the small Danish town of Slagelse, 50 miles southwest of Copenhagen. The daughter of a pharmacist, she was studying French for a teacher's certificate when, in 1910, she met Neils Bohr, a friend of her brothers. A year later they were engaged and they married in a brief civil ceremony in 1912. They had six sons, though they lost one to disease and one to a sailing accident. The other four grew up to have successful careers – Hans became a doctor; Erik, a chemical engineer; Ernest, a lawyer and Aage, a theoretical physicist who followed his father as Director of the Institute for Theoretical Physics in Copenhagen.

It was not luck, rather deep insight, which led him to find in young years his wife who, as we all know, had such a decisive role in making his whole scientific and personal life possible and harmonious.

– A friend of the Bohr family

For years, Margrethe acted as her husband's assistant, taking dictation and typing numerous drafts of his papers. She became the sounding board for his theories and was privy to his scientific ideas and process.

In the 1930s the family lived in the "Residence of Honor," a palatial mansion on the grounds of the Carlsberg Brewery. This was an honor bestowed upon Niels by the Danish government that was reserved for the nation's most respected scientists. Margrethe presided over the many receptions held for visiting scientists and foreign dignitaries, including Queen Elizabeth II and Indian Prime Minister Jawaharlal Nehru.

Difficulties came to the Bohr household when the Germans occupied Denmark in 1940. Though baptized as a Christian, Niels' mother was Jewish, which marked him in the eyes of the Nazis. The Gestapo ordered Danish Jews to be rounded up in 1943, and an arrest was pending for Niels. The family was divided up and sent on separate fishing boats to Sweden where they were reunited. Margrethe and three of their sons remained in Sweden for the rest of the war, while Niels continued on to England and then, with their son Aage, traveled to America.

Thirty-one years after the death of her husband, Margrethe Bohr passed away at the age of 95. She is buried with Niels in Copenhagen.

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Werner *Heisenberg* BIOGRAPHY

Werner Heisenberg was born on December 5, 1901 in southern Germany's charming village of Wurzburg. The son of a university professor, Heisenberg studied theoretical physics under Arnold Sommerfeld at the University of Munich. During the winter of 1922-1923 he went to Gottingen to study under Max Born, James Franck and mathematician David Hilbert. During a 1922 lecture given by Niels Bohr, Heisenberg publicly questioned the mathematics of the Nobel Prize winner, getting Bohr's attention. This prompted Bohr to invite Heisenberg on a hike, initiating their famous collaboration.

Since the measuring device has been constructed by the observer---- we have to remember that what we observe is not nature in itself but nature exposed to our method of questioning.

– Werner Heisenberg,
Physics and Philosophy, 1958

He received his doctorate from the University of Munich in 1923, then became an assistant to Born at Gottingen. In 1924 he went to Copenhagen to work with Bohr, under a Rockefeller Grant, through 1925. Heisenberg returned to Germany in 1927 to teach physics at the University of Leipzig. Heisenberg is best known for his uncertainty principle of 1927. The principle posits limits to the accuracy of knowledge about atomic behavior, since the means by which the researcher measures such phenomena alters the behavior itself. Heisenberg was awarded the Nobel Prize for Physics in 1932 for establishing the field of quantum mechanics. He suggested that any theory of the atom must be based on observable phenomena and not pictorial constructs such as Bohr's nuclear model of the atom. Heisenberg believed that observable data could be culled to formulate a set of possible values for a hypothetical particle. This could then be used to calculate, through mathematical formulas, the probabilities of particular energy states and transitions among these states. Quantum mechanics had a profound influence on the development of atomic and nuclear physics by providing a model for calculating formulations such as critical mass.

Early in World War II, Heisenberg conducted chain reaction experiments for the Germans, using heavy water. These experiments led him to believe in the feasibility of a nuclear weapon. Within a few days of Germany's surrender, Heisenberg was captured by Allied forces and incarcerated, along with other German atomic scientists, at Farm Hall, an estate near Cambridge, England. Deeply patriotic, he returned to Germany in 1946 and, along with his colleagues, set about the reorganization of the Institute for Physics at Gottingen. In 1948 the Institute was moved to Munich and renamed the Max Planck Institute for Physics. Werner Heisenberg became its director.

In 1953 his theoretical work concentrated on the unified field theory of elementary particles, which he thought to be the key to a greater understanding of particle physics. In 1958 he published a paper that constituted a step toward a unified quantum theory with his longtime friend and colleague, Wolfgang Pauli. However, Heisenberg's promotion of the paper was so egotistical that he alienated Pauli and damaged his own reputation in the physics community. He continued to lecture into the 1970s, his topics becoming more philosophical. A battle with cancer ended his life in Munich in 1976. He was survived by his wife, Elisabeth and their seven children.

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From Atom *to* BOMB

Material objects are of two kinds, atoms and compounds of atoms. The atoms themselves cannot be swamped by any force, for they are preserved indefinitely by their absolute solidity.
– Titus Lucretius Carus (99-55 BC). *On the Nature of Things* I, 518.

Bohr and Heisenberg were instrumental in the formation of the atomic model, but the structure of the atom was determined through the research of many different scientists over the course of 150 years.

1789: Antoine Lavoisier noticed that the mass of the substances present after a chemical reaction is the same as the reactants prior to the reaction. This idea became known as "The Law of Conservation of Mass."

1808: John Dalton took this law, some experiments performed by Joseph Proust, some of his own experiments and devised an atomic theory which stated that (a) each element is made up of tiny particles known as atoms, (b) atoms of a specific element are identified, (c) chemical compounds form when atoms combine with each other, and (d) chemical reactions cause a reorganization of the atom.

1895: Sir J.J. Thomson discovers the electron, the extremely light, negatively charged particles orbiting inside the atom which give it its chemical properties.

1900: Max Planck discovers that heat energy is not continuously variable, as classical physics assumes. There is the smallest common coin in the currency, the quantum, and all transactions are in multiples of it.

1905: Einstein realizes that light, too, has to be understood not only as waves but as quantum particles, later known as photons.

1910: Ernest Rutherford shows that the electrons orbit around a tiny nucleus in which almost the entire mass of the atom is concentrated.

1913: Bohr realizes that quantum theory applies to matter itself. The orbits of the electrons around the nucleus are limited to several separate whole number possibilities, so that the atom can exist only in a number of distinct and definite states. (The incomplete, so-called "old quantum theory.")

1924: French Prince Louis-Victor Pierre Raymond deBroglie suggests that, just as radiation can be treated as particles, so the particles of matter can be treated as a wave formation.

1925: Heisenberg abandons electron orbits as unobservable. Max Born finds instead a mathematical formulation in terms of matrices for what can be observed—the effects they produce upon the absorption and emission of light.

1926: Erwin Schrodinger finds the mathematical equation for the wave interpretation and proves that wave and matrix mechanics are mathematically equivalent.

1927: Heisenberg demonstrates that all statements about the movement of a particle are governed by the uncertainty relationship: the more accurately you know its position, the less accurately you know its velocity and vice versa.

1928: Bohr relates Heisenberg's particle theory and Schrodinger's wave theory through the complementarity principle, according to which the behavior of an electron can be understood completely only by descriptions in both wave and particle form. Uncertainty plus complementarity become established as the pillars of the Copenhagen interpretation of quantum mechanics.

1932: James Chadwick discovers the neutron—a particle that can be used to explore the nucleus because it carries no electrical charge and can penetrate it undeflected

1932: Heisenberg opens the new era of nuclear physics by using neutron theory to apply quantum mechanics to the structure of the nucleus.

1934: Enrico Fermi in Rome bombards uranium with neutrons and produces a radioactive substance that he cannot identify.

1937: Bohr explains the properties of the nucleus by analogy with a drop of liquid.

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From Atom *to* BOMB

1939: Otto Hahn and Dr. F. Strassmann in Berlin identify the substance produced by Fermi's bombardment as barium that has only about half the atomic weight of uranium.

1939: Lise Meitner and Otto Frisch in Sweden apply Bohr's liquid drop model to the uranium nucleus and realize that it has turned into barium (and krypton) under bombardment by splitting into two parts with the release of huge quantums of energy.

1939: Bohr and John Wheeler at Princeton realize that fission also produces free neutrons. These neutrons are moving too fast to fission other nuclei in U-238, the isotope which makes up 99% of natural uranium and will fission only the nuclei of the U-235 isotope, which constitutes less than 1% of it.

1939: Frederic Joliot in Paris and Enrico Fermi in New York demonstrate the release of two or more free neutrons with each fission which proves the possibility of a chain reaction in pure U-235.

1939: World War II begins and Germany at once commences research into the military possibilities of fission.

1939: Albert Einstein, urged by Leo Szilard, writes a letter to President Roosevelt about the dangers the United States would incur if Germany developed an atomic weapon first.

1940: Otto Frisch and Rudolf Peierls in Birmingham calculate – wrongly – the minimum amount of U-235 needed to sustain an effective chain reaction.

1942: The Allies atomic bomb program, known as the Manhattan Project, begins.

1942: Fermi in Chicago achieves the first self-sustaining chain reaction in a prototype reactor.

1945: The Allies' advance into Germany presumably halts the atomic program there.

1945: The bomb is successfully tested in the United States in July and, in the following month, is used on Hiroshima and Nagasaki, Japan.

It did not take atomic weapons to make man want peace, a peace that would last. But the atomic bomb was the turn of the screw. It has made the prospect of future war unendurable.

– J. Robert Oppenheimer.
The Atomic Bomb and College Education
(1946)

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Interpretations *of* HEISENBERG'S *visit to* COPENHAGEN

Copenhagen focuses on three characters and their search for the truth of what took place one night in September, 1941 when Werner Heisenberg visited Niels and Margrethe Bohr. What was said, and why, is the backdrop to an examination of human motivations and morals.

Thomas Powers, in his book *Heisenberg's War,* gives the most sympathetic portrayal of Heisenberg and the father/son relationship he had with Bohr. He writes that the German physicist harbored a "vague hope" that somehow work on the atomic bomb in America could be stopped by reassurances passed on through Bohr. In his own words Heisenberg said: "I then asked Bohr once again if, because of the obvious moral concerns, it would be possible for all physicists to agree among themselves that one should not even attempt work on atomic bombs…."[1]

What Bohr heard, according to Powers, was that Heisenberg wanted to halt development of an Allied bomb.

When Bohr returned to his work at the Physics Institute after Heisenberg's departure, he told his colleagues that he was convinced Germany was building a bomb and began to doubt his own conclusions of 1939 that such a project could not be accomplished. Bohr was left with two things: the belief that the Germans had a bomb program, and a simple sketch Heisenberg had drawn—a box with sticks protruding from the top. Bohr was convinced Heisenberg's sketch illustrated the working principle of the bomb he was building for Germany. He passed this information on to British and American officials.

When Heisenberg returned to Germany he entered "a confusing period in which contending parties of scientists, military officers, interested civilians and high government officials struggled over the future and control of nuclear research in Germany."[2]

At three meetings in 1942, the concerned parties met with Albert Speer, Hitler's economic czar. Heisenberg persistently made the argument that a nuclear bomb was theoretically possible, but that it could never be built in time to affect the outcome of the war. Speer wielded the greatest power over the German economy. Being an architect by profession and not a scientist, he turned to Heisenberg for advice. If Heisenberg wanted to build the bomb, he had only to speak out. It is Powers' conclusion that Heisenberg intentionally stalled when asking for money for supplies and research because he did not want Germany, specifically Hitler, to get the bomb.

In *Uncertainty: The Life and Science of Werner Heisenberg*, David C. Cassidy provides a different interpretation. The German Culture Institute in Copenhagen was opened as a propaganda arm, where Bohr and other Danish scientists were "invited" by Carl Friedrich Weizsacker to attend Heisenberg's lectures on solar physics and cosmic rays in September, 1941. With the German Reich so firmly entrenched across most of Europe and with Heisenberg now getting ethical advice from German elders such as Max Planck and Max von Laue, there was no reason for Heisenberg to be in Copenhagen at that time. It is Cassidy's conjecture that Heisenberg had joined his friend and colleague Weizsacker "in a conscious or unconscious propaganda effort instigated by the Foreign Office subdivision under Weizsacker's father."[3] The visit was probably a test of Heisenberg's suitability for further propaganda lectures; for Bohr's wife Margrethe it was "a hostile visit."[4]

A comprehensive account of Heisenberg and his visit is given in Paul Lawrence Rose's book, *Heisenberg and the Nazi Atomic Bomb Project: a Study in German Culture*. He writes that Heisenberg's friend, Weizsacker, believed American scientists were experimenting with the development of a five kilogram atomic bomb and he wanted Heisenberg to find out what Bohr knew of Allied progress and if a bomb were feasible. But the behavior of the two men in Copenhagen did not bode well for a private conversation.

Weizsacker asserted his authority by bringing the director of the German Cultural Institute to Bohr's office unannounced, while Heisenberg antagonized

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his hosts by "speaking with great confidence about the progress of the German offensive in Russia and how important it was that Germany should win the war."[5]

By the time the momentous after-dinner conversation between Bohr and Heisenberg arrived, the atmosphere was already filled with tension and prejudice. Heisenberg began by asking Bohr if "physicists had the moral right to work on atomic problems during wartime. Bohr asked back whether I [Heisenberg] believed a military application of atomic energy were possible and I replied: Yes, I know that to be so. I put my question again and Bohr answered to my astonishment that the war work of physics in every country was unavoidable and therefore well-justified."[6]

Heisenberg went on to state that all politicians were men of amoral power and that supplying Hitler with the bomb was not much different from giving the bomb to others. Though we have no account of what Bohr said, Rose speculates that Bohr must have felt completely betrayed, first by Heisenberg's collaboration with the Nazi regime and second, by the attempt to compromise the Danish physicist's own reputation.

Rose also writes that Heisenberg's presentation to Bohr had two thrusts: one political, the other scientific. In 1941 a new European order under German domination seemed inevitable. Heisenberg might have appealed to Bohr's belief in the social responsibility of the scientist by suggesting collaboration in the New European Order after World War II; scientists had to cooperate in order to restrain the evil aspects of politics and promote sound scientific progress. Heisenberg had a vision of a rosy postwar era, so in reality, he had been offering Bohr the opportunity to collaborate on exploiting atomic energy in a Nazi led Europe. "Seen in this dual political and scientific context, it seems clear that what upset Bohr, and turned him permanently against Heisenberg, was not fear that a German atomic bomb was imminent, but rather disgust that Heisenberg was planning for atomic research in some imminent *Pax Nazica*. It seemed that Heisenberg had totally forgotten the humanity and decency that had earlier bound him to Bohr."[7]

To this account Rose adds his views on German culture that shaped Heisenberg's character. Heisenberg knew of the German plunder of occupied Europe and the concentration camps, but his attitude was an example of German amoral politics: the belief that might is always right. Heisenberg regarded the crimes of Nazi Germany as less significant than the preservation of Germany herself—and, above all, German science.

Finally, Heisenberg saw himself as an "intense nationalist."[8] As such he had the characteristic deference to the authorities in control of the nation. As Walter Schiel, Federal German President, said in 1979: "These extraordinarily gifted people had a childish relationship to the state. State and Fatherland were simply equated. Whatever the state demanded from them, that was demanded by the Fatherland."[9]

Hence, a final speculation; Heisenberg and Bohr had a father/son relationship. When the father, Bohr, disappointed the son, Heisenberg returned to the only father he had left – Germany.

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Bohr's VIEW

The formidable power of destruction which has come within reach of man may become a mortal menace unless human society can adjust itself to the exigencies of the situation….We have reached the stage where the degree of security offered to the citizens of a nation by collective defense measures is entirely insufficient.

– Niels Bohr, 1945.[1]

Between 1957 and 1962, Niels Bohr wrote or dictated several letters to Heisenberg that were never sent. The documents were deposited by the Bohr family at the Niels Bohr Archive with the stipulation that they would only be released in 2012, fifty years after Niels Bohr's death. Historians and scientists had always speculated about the meeting between Bohr and Heisenberg in 1941, but the production of the play *Copenhagen* renewed and strengthened the already intense debate about what transpired that night. In order to accommodate the present interest and avoid further speculation, the family decided to remove the 50-year clause and release the letters/documents in February 2002. There are eleven documents in all, but not all address the 1941 meeting.

Written in 1957, Document 1 is an unsent letter to Heisenberg about his statements in a book by Robert Jungk, *Brighter than a Thousand Suns*. Bohr says that he remembers every word of their conversations that took place during the difficult time of the Nazi occupation of Denmark and accuses Heisenberg of faulty memory. On their visit the impression was made by Heisenberg and Weizsacker that Germany would win the war and so it was folly for the Danes to expect a different outcome and to resist all German offers for cooperation. Bohr continues that he received the impression that Heisenberg was the leader in the German development of atomic weapons and needed no discussion of "details" because he had been working on preparation for the last two years. Bohr writes that he was shocked that Germany was so vigorously pursuing an atomic weapon and wanted to be first in the race.

Documents 2 and 3 are unsent letters of congratulation to Heisenberg on his 60th birthday (December 5, 1961) while number 4 is a thank you reply from Heisenberg on a congratulatory telegram from Bohr. Document 5 is a thank you from Bohr to Heisenberg, never sent. Document 6 is an undated draft in which Bohr recounts Heisenberg's conversation of 1941, but adds that in conversations with his assistant, Christian Moller, Werner and Weizsacker felt the attitude of Danish physicists was unreasonable and indefensible; lack of cooperation could only bring disaster to Denmark.

Documents 7, 10 and 11 are all draft letters to Heisenberg, seemingly from the last two years of Bohr's life and all addressing the 1941 meeting. Bohr writes that since Heisenberg had said that the war would be decided by atomic weapons, Bohr could not believe that German scientists were working in any other direction. German physicist, Hans Jensen visited Bohr in 1942, telling him that German physicists were only considering atomic science for energy generation. Bohr remained cautious because of rumors from Germany about new weapons and his feelings of impending German arrest. Finally, in document 11, Bohr finds Heisenberg's statements that German physicists were trying to prevent the production of atomic bombs absolutely incomprehensible.

Bohr's letters to Heisenberg indicate a preoccupation with the Copenhagen visit and his desire to be understood. Why they remained unsent is the mystery.

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Names *and* PLACES *in the* Play

Max Born and **Pascal Jordan**: worked on the mathematics of quantum theory which Heisenberg used.

Hendrik Casimir: young physicist at Bohr's institute who worked on problem of superconductivity.

James Chadwick: British physicist who discovered the neutron.

Kurt Diebner: German army research expert for nuclear physics and explosives.

Paul Dirac: French physicist who discovered the relativistic wave equation.

Albert Einstein: the scientist who began it all with his theory of relativity, $E=MC^2$.

Enrico Fermi: Italian physicist who first produced the world's first sustained nuclear chain reaction in Chicago.

Otto Frisch: physicist who used Bohr's liquid drop theory to bombard uranium atom.

George Gamow: Russian physicist who first defined nucleus like a drop of liquid in 1928.

Gottingen: site of university that was and is one of the scientific centers of Europe.

Samuel Goudsmit and **George Uhlenbeck:** Dutch physicists who introduced the hypothesis of spinning electrons.

Otto Hahn: won the Nobel Prize for discovering nuclear fission.

Lise Meitner: Austrian physicist who helped Otto Hahn in the discovery of nuclear fission.

Christian Moller: Bohr's assistant who first suggested the possibility of a chain reaction.

J. Robert Oppenheimer: the principal scientist in guiding the atomic bomb project in Los Alamos, NM, known as the Manhattan Project.

Wolfgang Pauli: Austrian Nobel Prize winning physicist who helped lay foundations of quantum theory of fields and recognized existence of neutrinos.

Hans Petterson: Swedish physicist who worked on the disintegration of elements.

Max Planck: discovered the quantum law of radiation which laid the foundations for quantum theory.

Stefan Rozental: Bohr's Polish assistant in 1941.

Erwin Schrodinger: physicist who discovered wave mechanics that put quantum theory on a mathematical basis. Cyclotron-particle was invented by Ernest O. Lawrence in 1930.

Arnold Sommerfeld: Heisenberg's mentor at University of Munich in 1920. Worked on the quantum-mechanical theory of metals.

Albert Speer: Germany's Minister for Armaments and War Production. Later, Minister of Economy.

Leo Szilard: Hungarian physicist who enlisted Albert Einstein's help in warning President Roosevelt that Germany might be building a nuclear weapon.

Carl Friedrich von Weizsacker: physicist, collaborator and close friend of Heisenberg. His father was chief of the Foreign Office in Nazi Germany.

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Glossary *of* TERMS

Atom: The smallest naturally occurring, electrically neutral form of matter. Atoms are often referred to as the "fundamental building blocks of the universe." An atom consists of a positively charged nucleus, which contains protons and neutrons, surrounded by a cloud of negatively charged electrons.

Atomic Bomb: This generally refers to an explosive device that works on the principle of nuclear fission (as opposed to nuclear fusion, as in the hydrogen bomb). Fission bombs can use either plutonium or uranium. With uranium, several pieces, each smaller than critical mass, are blasted together by a so-called "gun assembly," forming a super critical mass of uranium that undergoes and explosive fission chain reaction.

Cadmium: A natural element found in the earth's crust, resistant to corrosion and a good conductor of electricity. It is often used in batteries and nuclear reactors as it quickly absorbs neutrons.

Chain reaction: A chain reaction occurs in fissionable material when neutrons from the high-energy fragments of a split nucleus induce fission in nearby nuclei; this will occur when the amount of material exceeds the so-called critical mass.

Critical mass: The critical mass is the minimum mass for which a chain reaction will occur in a fissile material. The fission of a nucleus yields two fragments of approximately equal size. These fragments tend to be in a highly energetic, unstable state, and boil off excess energy by ejecting fast neutrons. An ejected neutron can then encounter another nucleus where it can induce fission, be captured by this nucleus or just be scattered away toward another nucleus. The more nuclei this neutron encounters, the better chance it has of causing another nucleus to split.

Cyclotron: A cyclotron is a machine that accelerates charged elementary particles to very high-energy states. A beam of the particles to be accelerated moves in an evacuated chamber under the influence of a very strong magnetic field. As the charged particles rotate around the circular device, they receive an accelerating kick from an electric field twice during each orbit. After many such orbits, the charged particles are moving at speeds slightly less than the speed of light and have enormous energies.

Electrons: Electrons are negatively charged particles that surround an atomic nucleus. Although an electron has measurable mass, its special structure, if it has any, is smaller than any existing apparatus can resolve. The electrostatic attraction between the electrons and atomic nuclei is much weaker that the forces that hold the nucleus together.

Fission: The process whereby a heavy, unstable nucleus splits into two approximately equal fragments, releasing an enormous amount of energy. Fission can occur spontaneously or as a result of a collision between a nucleus and an energetic particle such as a neutron.

Fusion: Involves the joining of two lighter elements into a single, heavier nucleus. In this case, the heavier nucleus is much more stable than the lighter nuclei, and is thus in a lower internal energy state. The difference in internal energies is released in the fusion process.

Gone critical: The point in an atomic chain reaction when it becomes self-sustaining.

Quantum Theory/Quantum Mechanics: The physical theory that attempts to describe the motions of atomic and sub-atomic particles. Perhaps the most interesting distinction between quantum mechanics and classical physics is that in the classical theory, if a particle's position and momentum are known at some point, together with all forces acting on it, then its motion at any time in the future can be known exactly. In this sense, classical physics is deterministic. In quantum mechanics, exact predictions of a particle's motion cannot be made, only statistical probabilities can be calculated. Also, because measurements on a quantum system actually change its state, the concept of information is much more complicated than it is in classical physics; indeed, it is not even possible to measure position and momentum simultaneously for a quantum system.

Theory of Relativity: Developed by Albert Einstein, this theory states that matter and energy were really the same thing only in different form. If matter could be converted into energy, large amounts of power would be released.

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Final THOUGHTS: *A* Commentary

The year 1900 saw the culmination of outstanding achievements; it was a year of great stability and confidence. In fact, Lord Kelvin, President of Britain's Royal Society, proclaimed that everything of importance had already been discovered by science. Yet in 1900, ideas and theories began to surface that were to transform our world. For example, Max Planck published his first paper on the quantum theory and Albert Einstein graduated from Zurich Polytechnic Academy. A year later Werner Heisenberg was born while Henry Poincaré was working on difficulties involving Newtonian's mechanics which would explode into the chaos theory. Meanwhile, Freud published his *Interpretation of Dreams.*

In his book, *From Certainty to Uncertainty,* F. David Peat writes: "While the 20th century began with such confident certainty, it ended in unsettling uncertainty."[2] Despite all our knowledge and science, a terrible mess continues. Does this mean that reason and science are not enough? Peat is pessimistic and looks to Freud for a psychological hypothesis.

The eminent doctor believed humans are driven by two forces, Eros and Thanatos. "Eros is the libido or life instinct with its drive for pleasure, sexual release and survival…. Thanatos, or the Death Wish, seeks resolutions to all of life's tension by returning to an undifferentiated inanimate state of death."[3]

This desire to return to a helpless, infantile state has no resolution and constantly threatens to cause disruptive behavior. Though much of Freud has been discredited, his argument that desire for a civilization with laws and restrictions conflicts with the basic drives and desires of human nature.

Peat also offers a biological hypothesis. The human neocortex, the advanced part of the brain devoted to language, reflection and planning, is a recent evolutionary product. Anatomically placed on the early mammalian brain and the earlier reptilian brain, perhaps it is too young to control the irrational drives and impulses of these "older brains." Thus, human beings, at this stage in evolution are so flawed that societies cannot exist in a stable form.

It is Peat's theory that our higher functions—reason, imagination and memory—are creating problems. The fictions and fantasies manufactured by our thoughts become realities. The creative brain summons up enemies, foreigners, evil powers and economic threats—and these have become amplified by some scientists who monitor the heavens for asteroids or some politicians who plan more powerful weapons. Thought and creative powers have provided the modern world with triumph and technology, but also have produced war, violence and environmental disaster.

After September 11, 2001, we can look to no certainties such as external authority, organizations or experts to guarantee our security. Each of us must now take responsibility for the uncertain future… "a future that respects the rights and aspirations of all people, values the spirit of learning, celebrates the values of beauty and truth, and cares for our planet's health."[4]

Modern physics is just one, but a very characteristic part of a general historical process that tends toward a unification and a widening of our present world.

– Werner Heisenberg[5]

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ACTIVITIES

History

Discussion
What role does Einstein play in the creation of the atomic bomb?

• What might he have been thinking at that time?
• What plans did Niels Bohr put forth to control the implementation of international research on the bomb?
• How did Pearl Harbor affect American funding of atomic bomb research?
• What was the Manhattan Project and what was its role in ending the war in the summer of 1945?

Exercise
What stands in the way of accuracy when we describe a heightened and poignant situation in our lives? Can you recall a time when you were betrayed by a friend, disappointed by a grade or part of a losing team effort? Can you track what happened, and what you might have been thinking or doing that played a part in this outcome?

In class, discuss what it must have been like to be a German patriot such as Heisenberg trying to save his country without destroying the world. What could he see, and what could he not see, if he were to remain in Germany? Discuss what it must have been like for Bohr to meet up with his favorite student and protégé without knowing what part Heisenberg might be playing for the Nazis at this time.

Ask the class to take the part of Bohr in Copenhagen during World War II. Poll the class as to how many would have accepted a visit from Heisenberg and how many would have refused to see him during the war. Ask them to explain why they would/would not have seen him.

Language Arts

Discussion
Has the word communist changed for us since the fall of communism and since *glasnost* in Russia?

What do you think of when you hear that someone is a feminist or a liberal?

What do you think when you hear that someone is a conservative or reactionary?

At the 2000 Democratic Convention, President Clinton stated that America's success was not a matter of chance but a matter of choice. What meaning does the word *choice* hold for you?

Who would you say has control of shaping our language in today's world?

Should the government have a department of language that monitors the incorporation of new words and phrases into our written or spoken language? Why or why not?

Exercise
Politically-charged language was carefully devised by the Nazi government to exercise control over the German people and an occupied European population. Certain words such as *collaboration* and *surveillance*, held a meaning during World War II that they don't hold today. Discuss words and phrases that read in politically sensitive ways today.

Have the class come up with terms such as politically correct or incorrect that may imply negative connotations about the person being described.

For an interesting exercise, ask the students to use these phrases and words in sentences that are politically charged and to use the same terms in a sentence that can remain neutral of political connotations.

Discuss the pros and cons of politically-charged language. In what ways might it be helpful and in what ways is it destructive to society to label behavior?

Brainstorm with the students some terms they feel have a negative connotation in describing others. What do they think about using these words and the part language plays to create negative and positive meanings?

Behavioral Studies

Discussion
When is competition a good thing?

When is competition a bad thing?

Do nations need to compete to hold their own in the world at large?

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Are competition and cooperation mutually exclusive?

Are competition and cooperation ever compatible?

Exercise
In class, discuss the development and the deployment of the bomb in World War II. Given their viewpoints on the Allies developing and deploying the bomb, and the Germans not developing the bomb, the Japanese refusing to surrender, who would students see as the nucleus or influencer in each instance? How might competition have entered into the decisions made by each group?

An interactive exercise on this subject is called Status Exploration. Students are given a card with a number. One is the lowest and 10 is the highest. Create a situation where a group of 10 people would all be together (e.g. standing in a movie line, grocery store, laundry, etc.). Have the students improvise a scene where the character they are playing must "act" their status according to the number they were given. The remaining students in the class (audience) must place them in order of importance/status. Follow up by asking what gives someone high or low status.

Discussion
How important are allies in your life?

Generally, can an individual function alone as effectively as he/she can with an ally?

Is it possible to support a friend who subscribes to different values and beliefs than you do? For example, can a liberal-minded individual support a conservative-minded individual as a friend?

At what point in a friendship or alliance might one need to choose one ally over another?

Exercise
Heisenberg is torn between his loyalty to his country and loyalty to his colleagues. Most often our loyalties can match up because our values and belief systems indicate similar-minded realms and relationships. The German nuclear team wants to connect to Bohr via his former protégé Heisenberg. Bohr and Heisenberg are caught up in two opposing worlds.
Think of a time when you were torn between two conflicting worlds, both containing allies that you needed for your emotional, spiritual and perhaps physical well-being. For example, have you been in a situation that puts you between a friend, a spouse or parent, or two friends who are at odds with each other yet both important to you? Write a letter to one explaining your feelings for them and your need for their presence in your life in spite of (or maybe because of) your alliance with the other person. Be specific in your explanation of how and why you need both people in your life. Don't hold back on the pragmatic as well as emotional benefits for you.

At the end, write an addendum paragraph describing why you wouldn't actually send this letter.

Discussion
Do you think that most of your ideas are unbiased?

Do you think it is possible to know any or all of your biases? If so, what are some of your biases? Is it possible for scientific ideas and inquiry to remain unbiased or less biased than those of other disciplines?

What is the difference for you between a bias and a moral value?

Is there a role for unbiased scientific inquiry in the discussion of human genetics?

Is it possible for this research to be impartial and unbiased?

Should a government agency be positioned to monitor this particular scientific inquiry?

Exercise
Even though Heisenberg was a brilliant scientist, he failed to do an important calculation that might well have led him and Germany to produce an atomic bomb. The question arises in *Copenhagen* as to why he doesn't make that calculation. In today's world we talk about positioning, and it's possible that Heisenberg wasn't positioned for various reasons to make that calculation. On the one hand, he was a theoretical physicist and the information he needed would have had to come from

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an analytical chemist. In the German academic hierarchy it would be unusual for a physicist to consult a chemist, while a similar social and academic hierarchy didn't exist among the Allies.

Have the students bring in scenarios from home, work and school situations in which they are positioned to get good and complete information, and others in which they are not positioned to get good and complete information. Who are the other people involved in their scenarios? What are the dynamics and values of the group? Would it be possible for them to change their position in the group if they wanted to? What would that take?

Have the class break up into groups of four to describe and share their scenarios. Ask several people to describe and share their scenarios with the class.

Science

Discussion
What was the Cold War? Why was the Cold War so important?

Was it necessary to bomb Hiroshima and Nagasaki?

Who is to blame for the bombings?

Should we consider using nuclear weapons against some countries?

Is there potential for a nuclear war in the future?

Who should decide whether nuclear weapons are used?

Exercise
In the play, Werner Heisenberg discusses with Niels Bohr the concern that atomic science will be used to construct weapons of mass destruction, the first nuclear bombs. Both Heisenberg and Bohr were concerned about the research they were doing and the impact their findings would have on the world. Since the late 1930s and 1940s much research has continued to be done in the area of atomic weapons, and these weapons have become more powerful than they were during World War II.

Divide the students into two groups. One group is an advocate of the use of nuclear weapons; the other group disagrees with the use of these weapons. After an opportunity to do research to support their positions, schedule a debate. Allow students to make opening statements on both sides of the arguments and then allow the debate to follow. Encourage students to use hard facts and not just opinion. They should gather statistics about the use of the weapons and the amount of money involved to produce and subsequently disarm many of these weapons.

Colorado Model Content Standard #1 for History; students understand the chronological organization of history and know how to organize events and people into major eras to identify and explain historical relationships.
Colorado Model Content Standard #1, #4, #5, #6 for Reading and Writing; students read and understand a variety of materials; students apply thinking skills to their reading, writing, speaking, listening, and viewing; students read to locate, select, and make use of relevant information from a variety of media, reference, and technological sources; students read and recognize literature as a record of human experience.
Colorado Model Content Standard #1, #2, #5, #6 for Science; students understand the processes of scientific investigation and design, conduct, communicate about, and evaluate such investigations; Physical Science: students know and understand common properties, forms, and changes in matter and energy; students know and understand interrelationships among science, technology, and human activity and how they can affect the world; students understand that science involves a particular way of knowing and understand common connections among scientific disciplines.

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