

The Priesthood of Science
University of Ottawa Press, 2008
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Sources and Weblinks

The sources for the four epigraphs that follow the Table of Contents are as follows:

- Francis Bacon's *The New Atlantis* (1627): A work of merely some forty pages, it is breathtaking in the power of its anticipation of the future. It is still in print in many different editions and is also available in its entirety on the Internet.
- Albert Einstein, Letter to Heinrich Zangger, 6 December 1917: *The Collected Papers of Albert Einstein*, vol. 8, *The Berlin Years: Correspondence, 1914-1918*, English translation by A. M. Hentschel (Princeton University Press, 1998), p. 412.
- Max Born, *The Born-Einstein Letters*, translated by Irene Born (New York: Walker & Company, 1971): letters dated 28 November 1954 (pp. 229-30) and 29 January 1955 (pp. 232-3).

For Einstein's life see Jürgen Neffe, *Einstein: A Biography*, translated by Shelley Frisch (New York: Farrar, Straus & Giroux, 2007). His writings on society and politics have been collected in *Einstein on Politics: His private thoughts and public stands on nationalism, Zionism, war, peace, and the bomb*, edited by David E. Rowe and Robert Schulmann (Princeton University Press, 2007). Also useful is Thomas Levenson, *Einstein in Berlin* (New York: Bantam, 2004).

An indispensable source for tracking Leó Szilárd's struggle to contain the threat of nuclear fission is *Leo Szilard, his version of the facts: Selected recollections and correspondence*, edited by Spencer R. Weart and Gertrud Weiss Szilard (MIT Press, 1978). Weart's *Scientists in Power* (Harvard University Press, 1979) tells the story of Frédéric Joliot and Irène Curie, who discovered artificial radioactivity in Paris in 1934 and shared the 1935 Nobel Prize in Chemistry. By 1939 they and their colleagues had worked out the theory of a chain reaction and a design for both a nuclear reactor and an atomic bomb using uranium—which explains why Szilárd was so worried about what was happening in Paris!

In early February 1939 Szilárd, then in New York, learned that the French team was preparing to publish a paper suggesting that bombarding uranium with neutrons would lead to a chain reaction. He sent Joliot a letter urging him not to publish; Joliot, who didn't know who Szilárd was, thought that this completely unexpected request was bizarre. After some further transatlantic exchanges Joliot made up his mind and sent the following telegram: "QUESTION STUDIED MY OPINION NOW IS TO PUBLISH REGARDS"; the paper appeared in *Nature* in April 1939. (For a full discussion see Weart and Szilard, *Leo Szilard*, chapter 2, and Weart, *Scientists in Power*, chapter 5.) After the Nazi invasion of France in May of 1940, Joliot and Curie entrusted some of their research notes and materials, along with a quantity of heavy water that had been recently purchased from Norsk Hydro in Norway, to two young colleagues, Hans von Halban and Lew Kowarski, who proceeded to smuggle them into England. Joliot deposited the rest of their research notes in a vault at the Académie des Sciences building in Paris just before the Nazi occupation of that city, where they remained hidden for the duration of the war.

The French team, as well as American, British, German and Russian scientists, had all concluded early on that heavy water would be the best moderator for a nuclear pile, but all also knew that this substance was difficult to produce in sufficient quantity. So most of them also tried to work with graphite; this material, however, was hard to obtain from industrial sources at the very high level of purity that was required. In 1940 both French and German research teams made errors in their calculations of how well graphite would serve as a moderator, leading them to abandon this line of inquiry. Early in that same year Szilárd and Fermi, working at Columbia University, did the calculation correctly, showing that a graphite-moderated reactor could work. Szilárd sent their paper on this subject to the journal *Physical Review* and asked that that it be accepted but not printed. When he told his co-author Fermi

about the hold on publication he had arranged, Fermi exploded, saying this was “absurd”; only the intervention by their boss at Columbia, George Pegram, who supported Szilárd, kept the paper from being published (Weart, pp. 144-5). Thereafter Szilárd worked like a man possessed to find a source for the graphite of requisite purity. At the University of Chicago in early December 1942, they used graphite blocks in the world’s first controlled nuclear fission reaction.

The correct graphite calculation was the first of three decisive nuclear discoveries—and three terrifying secrets—from that fateful year, 1940. The second followed in short order :

In late May Louis Turner, a physicist at Princeton, sent Szilárd a copy of a paper showing theoretically that when uranium-238 absorbed neutrons ... a new element, plutonium [would be produced]. Although Turner did not realize it, he had written the prescription for the easiest route to building a nuclear bomb. Szilárd wrote back at once to say that a paper of his own was being kept secret, which implied that an official move was underway to withhold papers. He persuaded Turner to write the *Physical Review* and delay publication. It was well he did so, for Turner’s paper could have been an essential clue for the Germans and others. (Weart, p. 145)

The third secret discovery was made in Britain by Otto Frisch and Rudolf Peierls. Frisch was a physicist and Austrian Jew who had fled to Britain upon Hitler’s accession to power in 1933. He traveled frequently back to the Continent, especially to work with Bohr in Copenhagen. He was Lise Meitner’s nephew, and he visited his aunt shortly after Otto Hahn’s 1938 paper (on the collision of a neutron with the uranium nucleus) had appeared. Hahn, a chemist at the University of Berlin, could not explain the result he had achieved; it was Frisch and Meitner who realized that atomic fission had occurred, and whose resulting paper on the subject contained the first public use of that term. Peierls was a German physicist of Jewish ancestry who had also fled in 1933. Their joint 1940 secret paper, known as the Frisch–Peierls Memorandum, showed that only a kilogram of pure uranium-235 was needed to sustain a chain reaction, and that if such a reaction was uncontrolled, it would produce an explosion of

staggering magnitude. (This calculation is the one that Heisenberg supposedly did incorrectly, thus greatly overestimating the amount of U-235 needed to make a bomb; see http://en.wikipedia.org/wiki/Werner_Heisenberg for a good discussion of the controversy on this point.)

Three fateful discoveries from the year 1940, which if they had become known to German scientists might have prompted the Nazi regime to embark upon an atom bomb project. A single individual, Leó Szilárd, appears to be solely responsible for the fact that two of the three remained secret. One may not unreasonably refer to all this as a close call.

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Max Born (1882-1970) came from the Prussian city of Breslau, which was also Fritz Haber's birthplace. Although the families of both of them were part of the Jewish community in that city, it is hard to imagine any two individuals more different in character than were Haber and Born. Again like Haber, he met Einstein at the University of Berlin, where Born had been appointed professor of physics in 1915, before his move first to Frankfurt and then, in 1919, to Göttingen.

In one of the narrative sections of *The Born-Einstein Letters* (pp. 149-51), Born relates a charming story from the period of social chaos in Berlin after the collapse of the German government at the end of the First World War. Workers' and soldiers' councils were being set up everywhere during the winter of 1918-9, and university students followed suit. At the University of Berlin one day, they kidnapped the Rector and other senior officials and marched them to the Reichstag, where the student council held its meetings.

Already in 1918 Einstein was a famous public figure as a result of his opposition to the war. So someone asked him to try to act as a mediator, whereupon he telephoned Born and proposed that he and a third colleague should go to the Reichstag together. There in a public meeting Einstein tried to persuade the students that academic freedom should be protected at the university. The students listened politely but declined to set the officials free, so the three emissaries walked over to the Reich Chancellor's office to seek a meeting with President Ebert. There too Einstein was recognized at once and the three of them were ushered into the president's office.

Nothing came of their mission that day, but Born comments: "We left the Chancellor's palace in high spirits, feeling that we had taken part in a historical event and hoping to have seen the last of the Prussian arrogance, the Junkers, and the reign of the aristocracy, of cliques of civil servants and the military, now that German democracy had won." In April 1933, however, his name was on the list of civil servants dismissed from their posts by the Nazis because they were Jews; he eventually found refuge at the University of Edinburgh. The depth of the personal bond forged between Born and Einstein during their Berlin years is evident on every page of their correspondence, but they never saw each other again after 1932. Their common feelings about science and society, illustrated in the epigraphs that appear after the Table of Contents, survived even Einstein's profound unease with quantum mechanics, for Born was one of the great founders of that discipline.

Gaia's memo in chapter 8 tries to give a sense of the extraordinary community of geniuses who flocked to Göttingen in the 1920s under the patronage of Max Born and James Franck. Among the young masters who were sent there to study with Born was Werner Heisenberg. The two of them, along with Pascual Jordan, were nominated for a Nobel Prize by Albert Einstein in 1928, but when the prize for the discovery of quantum mechanics was finally

awarded in 1932, it went to Heisenberg alone. Born was bitter about this, of course. Right after the announcement Heisenberg wrote privately to Born that the award was unjust, since it should have been made to the three of them jointly, and later, in the 1950s, he said so publicly.

Born received his own Nobel only in 1954, in the same year when Linus Pauling won his first prize, this one for chemistry. (The second, the Nobel Peace Prize, came in 1962; in the early 1950s, Pauling came within a hair's-breadth of beating out Watson and Crick in the race to discover the structure of the DNA molecule, and had he done so, without a doubt he would have garnered another Nobel.) Born's comment (p. 231) is: "I cannot say with any certainty whether I was right that the simultaneous award of the Nobel Prize to Linus Pauling and myself had anything to do with the fact that neither of us had anything to do with the practical application or the misuse of science for political purposes." Although he had not been recruited into the war effort, Born supported the participation of those who were, including in the American atom bomb project: "For under the given circumstances nothing else can be done to save the rest of our civilization." After he returned to Göttingen upon his retirement, Born (along with Heisenberg, Max von Laue, Wolfgang Pauli, Otto Hahn, C. F. von Weizsäcker, and others) was among the signatories of the "Declaration of the Eighteen from Göttingen" (1957), which opposed the re-armament of West Germany with atomic weapons.

In a letter to Einstein dated 15 July 1944, Born noted that a newspaper in Scotland had reported "that you have called upon intellectual workers to unite and organise some protection against new wars of aggression and to secure their influence in the political field. I was very glad when I read that" (p. 144). In this same letter Born advocated the formulation of "an international code of behaviour or ethics" for scientists and named Bohr in this context. A few months later Einstein replied (p. 148): "It is, of course, quite correct for you to allot the relevant priesthood to Neils Bohr."

The quintet of Bohr, Born, Einstein, Pauling and Szilárd will always have a special place of honour in that section of the pantheon of science that is reserved for those who were tormented by the role of science in society.

Heisenberg is a special case, of course, due to the never-resolved ambiguity (attributable to Heisenberg himself) about what was said during his notorious visit to Copenhagen, in occupied Denmark in 1941, to meet with his mentor, Neils Bohr, and then again on his return visit to Bohr in 1947, accompanied by a British army officer, because at that time Heisenberg was “in custody” in the hands of the Allies. The initial meeting is the subject of the well-known play by Michael Frayn, *Copenhagen* (1998); the Anchor Books edition (New York, 2000) has a useful essay by the play’s author on the lingering controversy.

The critical point about all this is what role Heisenberg had played in the wartime German evaluation of the possibility of building an atomic weapon. Thomas Powers wrote a long, fully-researched and carefully-reasoned book on this subject, *Heisenberg's War: The secret history of the German bomb* (New York: Little, Brown & Co., 1994), which is an indispensable resource for anyone interested in this subject. Powers concludes that Heisenberg made no effort during the war to try to persuade the German authorities that making an atomic bomb was feasible. In a footnote (note 27 on page 508) Powers writes: “The efforts [in the U.S.] of Arthur Compton and Ernest O. Lawrence in the fall of 1941 to convince Vannevar Bush that a bomb was feasible are recounted in detail in Rhodes, *The Making of the Atomic Bomb*, pp. 347ff.... On a theoretical level, the German and American research programs were at this point probably neck and neck. If Heisenberg had shared Compton’s zeal, a genuine race for the bomb probably would have followed, lasting until war’s end.”

The unique combination of events, during which a remarkable collection of individuals was creating a fateful new science at just the time when Europe was falling into the grip of fascist barbarism, continues to inspire new commentaries. Among the most interesting of recent works is the book by the University of Pennsylvania physicist, Gino Segre, *Faust in Copenhagen: A struggle for the soul of physics* (New York: Viking, 2007). His father, Emilio Segré, who won a Nobel Prize in Physics in 1959, was a student of Fermi's in Italy in the late 1920s. When Mussolini passed a law in 1938 banning Jews from holding university positions, Segré just happened to be on a summer visit to the University of California at Berkeley. He managed to find refuge there and later worked on the atom bomb project in Los Alamos—another one among the flood of talented Jewish scientists, all highly motivated by the fear that the Nazi regime might beat them in the quest, who were no longer in Europe, where they might have been pressed into wartime service by the fascist regimes, as a result of the murderous anti-Semitism which raged there.

Faust in Copenhagen tells the story of the last in an annual series of meetings involving seven physicists arranged by Neils Bohr in Copenhagen. The year was 1932, and present in addition to Bohr were Max Delbrück, Paul Dirac, Heisenberg, Paul Ehrenfest (a close friend of Einstein's), and one woman, Lise Meitner. (A seventh invitee, Wolfgang Pauli, decided to skip the meeting.) After their scientific discussions had been concluded, they staged a skit, written primarily by Delbrück, in the form of a parody of Goethe's *Faust* (1932 was the hundredth anniversary of Goethe's death).

In the skit Bohr was cast as the Lord, the absent Pauli as Mephistopheles, and Ehrenfest as Faust. (Ehrenfest, who had succeeded H. A. Lorentz at the University of Leiden, suffered from severe depression and in 1933 he killed himself and his son, who was afflicted with Down's syndrome.) As Segre explains, 1932 was a decisive year for atomic physics, with

the discovery of both the positron and the neutron—the latter ushering in the idea of nuclear disintegration, the first step on the road to nuclear fission. And decisive for European politics as well, of course. Of the seven participants in the series, all but Dirac and Bohr were Germans or Austrians. Four of them were of Jewish or part-Jewish ancestry (Bohr, Ehrenfest, Meitner, and Pauli). Only Dirac and Heisenberg survived the ensuing catastrophe living in their native countries.

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Some of the material in the Prologue refers indirectly to a mode of thinking that goes by the name of “evo-devo,” short for “evolutionary developmental biology.” There are many useful articles on this subject on the Internet, including the Wikipedia entry. For a longer treatment, see *Genes in Development: Re-reading the molecular paradigm*, edited by E. M. Neumann-Held and C. Rehmann-Sutter (Duke University Press, 2006).

The source for the epigraph for Part One is Dr. Jane Rogers, who was then Head of Sequencing at the Wellcome Trust Sanger Institute, Cambridge, UK. She was quoted by BBC News on 4 December 2002 (<http://news.bbc.co.uk/2/hi/science/nature/2536501.stm>), at the time when the journal *Nature* had just published a special issue on the sequencing of the complete mouse genome, which the journal has made available in its entirety, free of charge, on the Internet: <http://www.nature.com/nature/mousegenome/index.html>. (The mouse genome sequence itself is at: http://www.ensembl.org/Mus_musculus/index.html.) This is one example of the remarkable “public face” of molecular biology.

A 39-part made-for-television series entitled “ReGenesis” explores science-in-society issues with specific reference to genomics (<http://www.regenesistv.com/indexframeset.html>), and at its own website (<http://www.ontariogenomics.ca/education/regenesis.asp>) the Ontario

Genomics Institute offers a very useful “episode guide” with further discussion of those issues. The guide for episode 9 deals with the public availability of at least part of the smallpox virus genome, which attracted worldwide attention resulting from the success of a reporter for *The Guardian* (UK), James Randerson, in obtaining a fragment of smallpox DNA through the mail (14 June 2006): <http://www.guardian.co.uk/terrorism/story/0,,1797057,00.html>).

Those interested in Narciso’s story about his biological origins, related in chapter 1, may wish to read the article by Jamie Shreeve, “The Other Stem-Cell Debate,” *The New York Times*, 10 April 2005, and in particular, his discussion about the research program of Rockefeller University’s Dr. Avi Brivanlou. Another researcher commented on Brivanlou’s program as follows: “Literally nobody wants to see an experiment where two mice that have eggs and sperm of human origin have the opportunity to mate and produce human offspring,” says Dr. Norman Fost, professor of pediatrics and director of the bioethics program at the University of Wisconsin and a member of the National Academy of Sciences committee reviewing stem-cell research policies. “That’s beyond anybody’s wildest nightmare.”

Further to the discussion toward the end of chapter 2, see Marc Hauser, *Moral Minds: How nature designed our universal sense of right and wrong* (New York: HarperCollins, 2006) and Frans de Waal et al., *Primates and Philosophers: How morality evolved* (Princeton University Press, 2006). In the de Waal collection, the essay by Christine Korsgaard is especially relevant, e.g., the sentence on p. 118: “The distinctiveness of human action is as much a source of our capacity for evil as it is of our capacity for good.”

For more on the issue of traumatic victims’ memories and military applications, see Jonathan D. Moreno, *Mind Wars: Brain research and national defense* (New York: Dana Press, 2006), pp. 128-32.

The source for the epigraph for Part Two is *The Physicists*, a play by the Swiss writer Friedrich Dürrenmatt originally published in 1962. The English translation is by James Kirkup (New York: Grove Press, 1964), and the passage is on p. 76.

On the life and career of Fritz Haber (chapter 5) one can consult Daniel Charles, *Master Mind: The rise and fall of Fritz Haber, the Nobel laureate who launched the age of chemical warfare* (New York: HarperCollins, 2005).

Much of the information on Fritz Houtermans recounted in chapter 8 comes from my conversations with his son, Jan, which took place when we were both at the University of California, San Diego in the late 1960s. (Jan was later a professor at the University of Bern, where his father had held his last appointment.) The most complete published account of his remarkable life is in Thomas Powers' *Heisenberg's War*, pp. 84-112 (see also other entries in the book's index and chapter 9, note 12, p. 502, for Powers' sources). The message that Houtermans sent in 1941 to the émigré scientists in the U. S., saying that Heisenberg was trying to slow down any bomb project, will be found on pp. 106-7. The book that Fritz and a colleague wrote using pseudonyms, and originally published in German, is: F. Beck and W. Godin, *Russian Purge and the Extraction of Confession*, translated by Eric Mosbacher and David Porter (New York: Viking Press, 1951). It has long been out of print, of course, but one can still find copies from second-hand booksellers through Amazon.

Those interested in "The Evolution of Placental Mammals" (chapter 10) should consult above all else the great book by Sarah Blaffer Hrdy, *Mother Nature: A history of mothers, infants, and natural selection* (New York: Pantheon Books, 1999). Also useful is Louann Brizendine, *The Female Brain* (New York: Morgan Road Books, 2006). The epigraph for Part

Three can be found in the fine article by Cort A. Pedersen, “How love evolved from sex and gave birth to intelligence and human nature,” *Journal of Bioeconomics*, vol. 6 (2004), pp. 39-63; the sentence quoted is on p. 48. On *rattus* see Natalie Angier, “Smart, Curious, Ticklish. Rats?” *The New York Times*, 24 July 2007, and A. L. Foote and J. D. Crystal, “Metacognition in the Rat,” *Current Biology*, vol. 17 (2007), 551-5.

Chapter 12:

(1) Material on both the Franck Report and “Ötzi the Iceman” can easily be found on the Internet.

(2) The passage in the quotation that begins, “There are two ways of dealing with dangerous technologies,” is attributed to MIT’s Tom Knight and is cited in the 20-26 May 2005 issue of *New Scientist*, p. 46. The author wishes to apologize to the eminent Dr. Knight for the disrespectful comment made by Hera about this passage.

(3) The complete report entitled “Ignition of the Atmosphere with Atomic Bombs” (1946), prepared by F. von Konopinski, C. Marvin, and E. Teller, was declassified (approved for public release) by Los Alamos National Laboratory in 1979, but was then officially withdrawn again following the incidents of September 11, 2001. However, one can still easily find the document in its entirety on the Internet.

(4) The Brookhaven experiment using the relativistic heavy ion collider is also known as the “killer strangelet” disaster scenario, and one can find information about it on the Internet, using that phrase. For fascinating discussion of this risk scenario, see the article by Adrian Kent, “A critical look at risk assessment for global catastrophes” (2003), available on the Internet at: <http://de.arxiv.org/abs/hep-ph/0009204>.

Chapter 15:

Of all the contentious issues related to the post-2001 “war on terror,” none is more bizarre than the sinister terrorist attack on U. S. soil involving weaponized anthrax. This attack, launched by material distributed in letters through the U. S. postal system, occurred in October 2001, mere weeks after September 11, eventually caused 22 cases of inhalation anthrax, five of which were fatal. See D. B. Jernigen et al., “Investigation of bioterrorism-related anthrax, 2001: Epidemiologic findings,” *Emerging Infectious Diseases*, vol. 8, no. 10 (October 2002): <http://www.cdc.gov/ncidod/EID/vol8no10/02-0353.htm>. At the time of writing (December 2007), more than six years had elapsed since the events, and no one has ever been arrested for the crime; there is persistent speculation that someone who had worked at the U. S. Army’s bioweapons facility at Fort Dietrich, Maryland must have been involved. The President of the United States never mentions this unsolved mystery in the updates on the war on terror. Information available on the Internet from reliable sources shows that the material used in these attacks had an exceptionally high spore count (1 trillion per gram); in addition, its method of preparation showed a level of sophistication that could not have been attained by any “amateur” group. See, for example: Gary Matsumoto, “Anthrax Powder: State of the Art?” <http://www.sciencemag.org/cgi/content/full/302/5650/1492> (*Science*, vol. 302, no. 5650 [28 Nov. 2003, pp. 1492-7]). There are superb illustrations in this article.