The History of the Twentieth Century
Episode 307
"The Certainty Principle"
Transcript

[music: Fanfare]

One aim of the physical sciences has been to give an exact picture of the material world. One achievement of physics in the twentieth century has been to prove that that aim is unattainable. There is no absolute knowledge and those who claim it, whether they are scientist or dogmatist, open the door to tragedy. All knowledge, all information is imperfect. We have to treat it with humility.

Jacob Bronowski, *The Ascent of Man.*

Welcome to *The History of the Twentieth Century.*

[music: Opening Theme]

Episode 307. The Certainty Principle.

Shall I teach you what knowledge is? When you know a thing, to hold that you know it; and when you do not know a thing, to allow that you do not know it—this is knowledge.

Confucius. *Analects*, Book II, Chapter 17.

Euclid of Alexandria was born around the year 300 BC, or around the year 200 After Confucius, if you like, and he must surely be included on the list of the most important mathematicians of all time. His textbook, *Elements,* is the best known and most widely used textbook of all time. They were still teaching geometry by the Euclidean method, more or less, when I was in high school. Do they today? It's hard even to imagine teaching it any other way.

Euclid begins his work by laying out some easily grasped definitions and concepts: point, line, angle, plane, circle, triangle, and so on, then gives a few basic postulates, such as, a straight line may be drawn from any point to any other point. From these simple beginnings, he goes on to build out a bewildering array of geometrical conclusions, every new one derived from the earlier ones and those simple beginnings, relying on elegantly crafted chains of deductive reasoning.

Apart from what Euclid's work teaches us about geometry, its very process stands as a breathtaking intellectual achievement. Albert Einstein called *Elements* a holy book. In 1922, American poet Edna St. Vincent Millay penned a line that declared, "Euclid alone has looked on Beauty bare."

A work as admired as this one, for as many centuries as this one, naturally inspires, and one ambition it inspired was to build further on Euclid's work, until you built out a full system of mathematics that answers every problem, completely and consistently, based on Euclid's simple beginnings.

The 19th century saw the emergence of mathematical logic, that is, the refinement of formal logic into something like a branch of mathematics. By the beginning of the twentieth century, one could dream of a future in which the tools of mathematics—theorems, proofs, algebraic formulation and solution—could be employed to construct ideas and systematize logical reasoning. Perhaps human thought itself could be purged of its primitive messiness and made as thorough, elegant, and unassailable as Euclid's geometry. What a heady vision.

German mathematician David Hilbert was a major figure in the field at the dawn of the twentieth century, and Hilbert was very much inspired by this vision of mathematical logic's potential. In 1899, he published *Foundations of Geometry*, an attempt to refine and expand on Euclid. Later came the heftier *Foundations of Mathematics*. He batted around ideas on relativity with Albert Einstein and taught up-and-coming mathematicians like John von Neumann and theoretical physicists like Eugene Wigner.

In 1925, when he was 63 years old, Hilbert developed a case of pernicious anemia, which was untreatable at the time. He could no longer work as he had before and retired in 1930. In German scientific circles at the time, one heard the Latin maxim, *ignoramus et ignorabimus*, that is, "We do not know and we shall not know." This sentiment was anathema to Hilbert, who never abandoned his vision of the power of mathematics to extend human knowledge. In his retirement address to the 1930 meeting of the Society of German Scientists and Physicians in Königsberg, he defiantly declared his own conviction that *"Wir müssen wissen. Wir werden wissen,"* that is, "We must know. We shall know." When Hilbert died in 1943, those words were carved on his tombstone.

Ironically, in Königsberg at the same time, at the same conference, was a 24-year-old Austrian doctoral student named Kurt Gödel. Kurt Gödel was born in 1906 in the German-majority city of Brünn that became part of Czechoslovakia in 1918, when Kurt was just 12 years sold. In other words, Kurt Gödel and his family were Sudeten Germans, and like many Sudeten Germans, Kurt continued to think of himself as an Austrian, despite the events of 1918.

He began attending the University of Vienna in 1924. He was at first interested in theoretical physics, but after studying the work of English philosopher Bertrand Russell and attending a lecture by David Hilbert, he became interested in mathematical logic, regarding it as the foundation of everything else in mathematics and science. In 1929, as he was finishing up his doctoral dissertation, he became an Austrian citizen. In 1930, he received his doctorate and attended that conference I spoke of, where he first began to discuss his dissertation, which was published soon after, in 1931, by the Vienna Academy of Science, under a title which begins, “On Formally Undecidable Propositions…”

You see, mathematicians like David Hilbert aspired to build a logical system that was consistent and complete. In this context, consistent means that your system has no contradictions. If you could put together two different proofs within your system of logic, one of which proves that $a=b$, and the other of which proves that $a \neq b$, then your system of logic is not consistent. David Hilbert says you have to do better.

Complete means that within your logical system, every proposition that is true is provable. If there exists a statement which is true but cannot be proven, then your system is incomplete, and David Hilbert remains unsatisfied.

Then along came this young upstart, Kurt Gödel. He demonstrated that there can *never be* a logical system that is both complete and consistent. This stuff can get esoteric and mind-bending, but at the root is a simple principle. Imagine that you are testing a system of logic to see whether it works; whether it is complete and consistent. Now imagine you are using this system of logic to derive this proposition: “This proposition cannot be proved.”

So what happens? If you prove the proposition, then you have proved that what you have proved cannot be proved. That’s a contradiction. The system is inconsistent. On the other hand, if you can’t prove the proposition, then the proposition is true, but can’t be proved. The system is incomplete. Since any given proposition must either be provable or not provable, you lose either way. Therefore, the perfectly complete and consistent system Hilbert sought can not exist.

[music: eDeam]

The Principle of Uncertainty is a bad name. In science, or outside of it, we are not uncertain; our knowledge is merely confined, within a certain tolerance. We should call it the Principle of Tolerance. And I propose that name in two senses. First, in the engineering sense: Science has progressed, step by step, the most successful enterprise in the ascent of man, because it has understood that the exchange of information between man and nature, and man and man, can only take place with a certain tolerance. But second, I also use the word, passionately, about the real world. All knowledge–all information between human beings –can only be exchanged within a play of tolerance. And that is true whether the exchange is in science, or in literature, or in religion, or in politics, or in any form of thought that aspires to dogma. It’s a major tragedy of my lifetime and yours that scientists were refining, to the most exquisite precision, the Principle of Tolerance–and turning their backs on the fact that all around them, tolerance was crashing to the ground beyond repair. The Principle of Uncertainty or, in my phrase, the Principle of Tolerance, fixed once for all the realization that all knowledge is limited. It is an irony of history that at the very time when this was being worked out, there should rise, under Hitler in Germany and other tyrants elsewhere, a counter-conception: a principle of monstrous certainty. When the *future looks back on the 1930s, it will think of them as a crucial confrontation of culture as I have been expounding it – the ascent of man against the throwback to the despots' belief that they have absolute certainty.*

Jacob Bronowski, *The Ascent of Man.*

Albert Einstein's work on relativity demonstrated that there is no such thing as an objective frame of reference. There is only your frame of reference or my frame of reference or someone else's frame of reference. All observations of time and space are limited to the frame of reference in which they were made. They may be true in your frame of reference, but not in mine.

Werner Heisenberg's work on the uncertainty principle demonstrated that in the realm of nuclear physics, basic properties of subatomic particles, properties like position and velocity, are unknowable beyond certain limits. And let me emphasize again, as I did in episode 246 when I first brought up this subject, the uncertainty principle does not mean merely that there is some fundamental limit on our ability to measure the position or velocity of a particle. It means that the particle doesn't *have* an exact position or velocity. To quote Gertrude Stein, there is no *there* there. This is a consequence of the fact that particles are also waves. For instance, subatomic particles can move from here to there without passing through the space between. They can appear and disappear spontaneously.

Einstein published the general theory of relativity in 1915. Heisenberg published his groundbreaking work on uncertainty in 1927. In 1931, along came Kurt Gödel, pointing out that logic itself has its own inherent limitations.

To these three names—Einstein, Heisenberg, and Gödel—we might add Sigmund Freud, whose work straddles the 19th and twentieth centuries. Freud's key insight is that there is a portion of the human mind we are not consciously aware of but which influences our thinking. No matter how objective and logical we may try to be, there lurks in the back of our thoughts something shaped by our experiences, our desires, and our fears, that shades our thinking, although we are not aware of it. Maybe we should toss Karl Marx into this mix as well; his work appeared in the 19th century, but it has in common with these other thinkers that it brought fundamental reinterpretation to what were previously believed to be fixed and unchangeable certainties. In Marx's case, these certainties were economic and social. And what the heck, let's throw in Arnold Schönberg, the pioneering theorist of atonal music, who challenged most of the basic theoretical assumptions of Western music.

In 1973, Jacob Bronowski created for the BBC a thirteen-part documentary series titled *The Ascent of Man.* It was an examination of the history of humanity with emphasis on scientific and technological breakthroughs. I watched this series back in 1974, when it premiered in the United States. I've been waiting until this moment in *The History of the Twentieth Century* to acknowledge this: That Jacob Bronowski is right up there with Barbara Tuchman as a patron saint of this podcast. It was their approach to history that inspired me to present this podcast in this way.

I know some of you listening have also been thinking about Jacob Bronowski as you listen to this podcast, and some of you have picked up on the fact that Bronowski influences my thinking, because a couple of you have written in to tell me so. And if you saw *The Ascent of Man,* it was probably episode 11 of the 13, the one titled "Knowledge and Certainty," that stuck with you the most. The quotations from Jacob Bronowski that I read to you earlier came from this episode.

Einstein, Heisenberg, Gödel, Freud, Marx, Schönberg. What do all these people have in common, besides the revolutionary nature of their work? They are all Germans, or at least were all German speakers. There are caveats. Freud, Gödel, and Schönberg were born in Austria. Einstein, Freud, and Schönberg were born to Jewish families, though none of them were very religious themselves. Einstein did some of his most important work in Switzerland; Marx in England. Still, they are all products of German-speaking cultures.

None of them are nihilists. None of them are saying we cannot know anything, but they are setting defined limits on how much we can know and questioning premises that were previously regarded as certainties. They are telling us that our knowledge is subject to a certain tolerance, a little wiggle room of plus-or-minus, as Bronowski noted in the quote I read a few minutes ago.

And it was Bronowski who first pointed out, to me at least, the remarkable historical coincidence that the modern research that was exploring the limits on what can be observed and measured and understood by the human mind emerged within the same community of people from which was also emerging what Bronowski calls the "monstrous certainty." Nazism.

There are three great intellectual ironies of this era that I want to talk about today, and this is the first one: how knowledge of uncertainty arose in the same human community as did the monstrous certainty of fascism.

Albert Einstein was all too familiar with this coincidence. In August 1920, a German war veteran named Paul Weyland, who had no academic credentials whatsoever, organized a meeting at the Berlin Philharmonic Hall dedicated to attacking Einstein and his theory of relativity, at which Weyland himself was the keynote speaker. Instead of critiquing the theory on scientific grounds, he denounced Einstein as part of a cabal of academics driven by what he called "Jewish arrogance" to employ "mass suggestion" to delude the German people. The most memorable moment from this speech was when he declared that relativity was "scientific Dadaism." In other words, Einstein isn't wrong because he's wrong; he's wrong because his theory will cause people to think and create and act in ways of which I personally disapprove.

Weyland seems to have been more of a con man than anything, and not a particularly influential figure, but he was one of the first to articulate a criticism of relativity you still hear in our day.

A more serious figure was Philipp von Lenard, an ethnic German born in what was then Pressburg, Hungary, and after the war, Bratislava, the capital of Slovakia. Lenard was an actual physicist, who won the 1905 Nobel Prize for his work on cathode rays. He was also an ardent German nationalist. In 1914, he was one of the 93 German scientists who signed a manifesto in defense of Germany's conduct of the Great War, which I talked about back in episode 108.

Lenard never got over that academic/political spat. He began to speak disparagingly of "British physics," arguing that British research in the field was merely derivative of, if not outright plagiarized from, German physics. After the war, Lenard was inspired by Weyland to take up his campaign against Albert Einstein and his work on relativity. Aside from criticism of the theory itself, Lenard, like Weyland and a few others, argued that Einstein's work drew upon a "Jewish spirit," that it was based on the Talmud, and similar nonsensical claims. Lenard eventually came to dismiss relativity as "Jewish physics," a deceptive method based purely on mathematical argument that defied common sense, as opposed to "German physics," which relied on rigorous experiment and observation. In 1922, when Germany's foreign minister Walter Rathenau, who was Jewish, was assassinated, Albert Einstein, as one of the most prominent Jewish people in Germany, found himself the target of death threats, forcing him and his family to leave their home in Berlin for a time.

Einstein seldom answered these critics directly. When he did, he suggested that their criticisms were based on a misunderstanding of his work, along with anti-Semitism. His critics responded by denying any prejudice and accusing Einstein of using the claim of anti-Semitism merely to discredit legitimate criticism. Does any of this sound familiar?

In 1931, a book was published in Germany attacking the theory of relativity titled *A Hundred Authors against Einstein.* Actually, it was 28 authors, plus excerpts from the writings of 19 more; the other 53 were merely names on a list of people supposedly opposed to Einstein's theory. Only a handful of the hundred were physicists or mathematicians; most of the others were claiming authority in a field they had no background in. Some were known anti-Semites or even Nazis—Lenard himself joined the Nazi Party in 1924—although the book itself steers clear of any mention of Judaism and even includes among its names a few Jewish contributors.

Critics lambasted this book. Einstein himself merely noted that if the theory of relativity were wrong, it would only require one author to prove it.

As a side note, I'll mention that there was also a certain amount of this also going on in the Soviet Union, similar to Lysenkoism. That is, a couple of Soviet physicists rejected relativity on Marxist-Leninist ideological grounds, but they were exceptional, and Soviet science generally embraced relativity and quantum mechanics with little argument.

Einstein was more fortunate than most Jewish academics in Germany. As the world's most famous scientist, he regularly visited other countries for meetings and to give lectures and had international contacts that would serve him well after Hitler became chancellor in 1933. At that precise moment, Einstein was a visiting professor at the California Institute of Technology. He and his wife were on their way home to Germany in March, just in time to receive the news of the passage of the Enabling Act in Germany, and shortly after that, the new German law that barred Jewish people from government positions, which included university professorships.

Einstein decided then and there, while he was in Antwerp, to be exact, that he could never return to Germany. He renounced his German citizenship. Soon afterward, the book burnings began, with Einstein's work prominent among those consigned to the flames. He stayed in Belgium for a time, got to know the Royal Family there, then visited Britain, where he met David Lloyd George, Austen Chamberlain, and Winston Churchill. Einstein received support from the Academic Assistance Council, founded by British economist William Beveridge, which provided aid to academic refugees from Hitler's Germany. In Einstein's case, this aid included bodyguards, since the Germans had put a price on Einstein's head.

Einstein toured Britain, speaking on academic freedom and deploring the treatment of Jewish people in Germany. In October, he spoke before a crowd of ten thousand at the Royal Albert Hall in London, who received him warmly. Einstein successfully lobbied the Turkish government to accept refugee academics from Germany, and it is a little known fact that Turkey stands alongside the United Kingdom and the United States as a major refuge for Jewish academics fleeing Nazi persecution.

A bill was introduced in Parliament to grant Albert Einstein UK citizenship, but it didn't pass. Instead, Einstein traveled to the United States, where he accepted a position at the newly created Institute for Advanced Study in Princeton, New Jersey, which is independent of Princeton University. Ironically, America's most prestigious universities, including Princeton, had tight limits on the number of Jewish students they would accept, and few or no Jewish faculty members. Einstein would receive US citizenship in 1940, and would remain at the Institute for Advanced Study until his death in 1955.

It was not only Jewish academics who suffered persecution under the Nazis. Ethnic German, Austrian, Italian, and Hungarian academics, among others, were also persecuted, some because they had Jewish spouses, or Jewish friends or associates, or simply because they embraced the work of Jewish scientists like Einstein too enthusiastically for fascist tastes. Figures like Eugene Wigner, Max Born, Hermann Weyl, Edward Teller, Enrico Fermi, and Kurt Gödel.

David Hilbert, old and ill and retired from his academic position, met the German minister of education, Bernhard Rust, at a banquet in 1934. Rust, defending Nazi policies, asked Hilbert whether the mathematics department at his university truly had suffered any as a result of the dismissal of Jewish scholars. Hilbert replied, "Suffered? It doesn't exist any longer."

And then there's the case of Werner Heisenberg, who first presented the uncertainty principle that still bears his name. Heisenberg was not Jewish. He wasn't even Austrian. He was as German as beer, bratwurst, and a generous helping of potatoes. But his work clearly fell within the scope of what Lenard was calling "Jewish physics." After Hitler became chancellor, the Nazis derided Heisenberg as a "white Jew;" that is, someone whose outward appearance was German—or Aryan, as they would have said—but was Jewish on the inside.

The criticism from the proponents of so-called “German physics” was sufficient to cost Heisenberg opportunities for professorships at several German universities. Fortunately for him, his mother happened to be on friendly terms with the mother of Heinrich Himmler, the head of the SS. Mama Heisenberg had a word with Mama Himmler, who had a word with her son, and Heinrich Himmler ordered Heisenberg cleared. He told his SS subordinates that Germany could not afford to lose Heisenberg, who potentially could teach a whole generation of German physicists, though he did warn Heisenberg that while it would be okay to talk about uncertainty or relativity or whatever, it would be better to stay out of politics and avoid crediting the Jewish scientists, like Einstein, who made these discoveries. Heisenberg would decline an invitation to emigrate to the United States and would continue to work on atomic research in Germany.

[music: *eDream*]

There is a second historical irony of this time, in the chilling coincidence that scientists in Europe were just coming to grips with the problem of how to make practical use of atomic energy at the same moment that fascism was rising all around them. It was Leo Szilard who first became aware of this dreadful synchronicity in 1933. I described to you in episode 278 how Szilard first conceived of the chain reaction as a practical means of harnessing and using the energy released when atoms were split as he was standing on a street corner in London.

Szilard also realized that such a chain reaction would make possible a real-life atomic bomb, to use the term coined by H.G. Wells, and saw the horrifying but very real possibility that it would be a German researcher who first identified which kind of atom had the right combination of properties to make a chain reaction possible. Szilard foresaw, even in 1933, just months after Hitler became chancellor, that if a Nazified Germany had atomic bombs, it would not shrink from using them, especially against people the Nazis considered inferior to themselves, people like Leo Szilard.

It was in fact German researchers who first identified a candidate material for an atomic chain reaction, though none of them were supporters of the Nazi government. There was the 59-year-old chemist Otto Hahn, his assistant, 37-year-old chemist Fritz Strassmann, both of whom were Germans, but known to be critics of the Nazis, and 59-year-old Jewish Austrian physicist Lise Meitner. Meitner was only the second woman to earn a doctorate in physics at the University of Vienna, and she worked together with Hahn and Strassmann at the Kaiser Wilhelm Institute in Berlin.

It was no secret that Meitner was Jewish, but she was able to keep her job at the Institute because she was an Austrian national, not a German.

In 1938, Italian physicist Enrico Fermi announced that he had bombarded uranium atoms with neutrons and produced unknown chemical elements he believed were transuranic, that is, that they had a higher atomic number than uranium had. In fact, what Fermi had done was split uranium atoms, but he did not yet realize this.

In Berlin, Hahn and Meisner and Strassmann tried replicating Fermi's work, bombarding uranium with neutrons. Then came the *Anschluss,* and suddenly Meitner no longer had the protection of foreign citizenship. She was a Jewish German now, and thus ineligible to continue her work. She had to leave the team. Danish physicist Niels Bohr was able to wrangle her a position in Stockholm, and there she became a Swedish citizen. Her nephew, Otto Frisch, had abandoned Germany in 1933. He was living in Britain, although at this moment he was in Copenhagen, working with Niels Bohr. In Berlin, Hahn and Strassmann continued their work without Lise Meitner.

Otto Frisch customarily visited his Aunt Lise in Berlin every year for Christmas. Well, Christmas 1938 found her in Sweden, so Otto went there for his holiday visit. Lise told him that she had just received a letter from her erstwhile colleague, Otto Hahn in Berlin, in which he brought her up to date on his and Strassmann's experiments. They were still bombarding uranium with neutrons and studying the results and had made a strange finding. One of the products of the bombardment appeared to be the element barium.

How could that be? Otto asked. It had to have been a mistake. No, said Lise, Otto Hahn was too good a chemist to make that big a mistake. You see, by 1938 atomic physicists had become accustomed to observing radioactive decay, in which an atomic nucleus gives off a proton, or an electron, or an alpha particle. That was old hat now. The loss of a proton or electron would change the nucleus's atomic number by one. The loss of an alpha particle would change it by two. In any of these cases, you can think of the process as a little piece of the nucleus being chipped away.

But uranium has an atomic number of 92 and barium has an atomic number of 56. No one had ever observed an atom changing its atomic number by 36 steps before. That was more than chipping off a little piece of the uranium nucleus; that was breaking it in two. The two of them did a little math on scraps of paper and realized that this would generate a staggering amount of energy.

Otto returned to Copenhagen and shared all this with Niels Bohr. Bohr slapped his forehead and said, "What idiots we have been!"

Otto Hahn and Fritz Strassmann published a paper in the German journal *Naturwissenschaften, The Science of Nature,* in January 1939, reporting their discovery of barium following neutron bombardment of uranium. In February, Lise Meitner and Otto Frisch published in the British journal *Nature* their calculations explaining the presence of barium in the Hahn/Strassmann result as a product of the splitting of the uranium nucleus. Frisch dubbed this process fission, by analogy to the biological term for cellular division.

These two publications sent shock waves through the small community of atomic physicists. One of the physicists who took note was Enrico Fermi, who had just been awarded a Nobel Prize for his own work in uranium bombardment. These new results showed that Fermi had in fact produced barium through nuclear fission, just as Hahn and Strassmann had, only he had misinterpreted the results. How embarrassing!

Fermi and his family had traveled to Stockholm in 1938 so he could receive his Nobel Prize. Afterward, instead of returning to Italy, they went to the United States. You see, in 1938, Fascist Italy had enacted its own version of Germany's Nuremberg Laws, restricting the rights of Jewish people. This was meant as an Italian gesture of friendship toward Nazi Germany. Fermi's wife was Jewish, and so were his two children, at least as far as the new law was concerned, so the Fermis moved to the USA. The newly acclaimed Nobel laureate was quickly offered a position at Columbia University in New York City.

Also recently arrived in America was Leo Szilard. He had left Europe after the Sudetenland Crisis, convinced that another European war was inevitable. Not being a Nobel laureate, he had more trouble finding a position. He bounced around the US from university to university, and was in New York City in January 1939 when Niels Bohr arrived to give a lecture at Princeton. Bohr visited Fermi at Columbia and told him about the work of Hahn and Strassmann and Meitner and Frisch.

Leo Szilard also got the news, from Eugene Wigner at Princeton, and he went tilt. The nightmare vision he'd had on that London street corner five years ago was about to become reality. He brought his fears to Enrico Fermi. Neutron bombardment of uranium released large amounts of energy. Did it also release neutrons? Was uranium the magic element that would make a nuclear chain reaction feasible, and with it, an atom bomb?

Fermi was skeptical. So Szilard borrowed $2,000 from a friend, got permission to use a laboratory at Columbia for a few months, and recruited the Canadian-born American physicist Walter Zinn to work with him. They would bombard uranium with neutrons, to see if the uranium released more neutrons than it received. A detector plugged into an oscilloscope would reveal the result. They ran the experiment, but the green line on the oscilloscope stayed flat. Zero neutrons detected.

None at all? Really? Then Zinn realized they had forgotten to plug in the detector. The oversight was quickly rectified and the oscilloscope went wild.

This was proof enough to convince Fermi to repeat the experiment on a larger scale, and he confirmed it. This was not a chain reaction, but it was evidence that it would be possible to trigger a nuclear chain reaction in uranium. Across the Atlantic, in Paris, a French team independently came to the same conclusion. That team included Frédéric Joliot-Curie, husband of Iréne and son-in law of Marie Curie.

In March 1939, Enrico Fermi made a presentation to the US Navy Department on the military implications of this research. The Navy agreed to a $1500 grant to Columbia University for further investigation. Fermi was disappointed. They didn't seem to be taking the matter seriously enough.

Meanwhile, disturbing news was coming out of Germany. That same month, March 1939, Germany took control of what was left of Czechoslovakia. As it happens, Czechoslovakia was the most important source of uranium ore in Europe, and after the takeover, the German government embargoed the export of uranium, strongly suggesting to these expatriate physicists in the United States that Berlin was already aware of its potential military significance. Physicists in Germany were publishing papers speculating about using nuclear fission to power what they called an *Uranmaschine*, literally a "uranium machine," that is, what we today would call a nuclear reactor.

The most important source of uranium in the world at the time was the Congo, which was controlled by Belgium. Leo Szilard and Eugene Wigner discussed this and felt someone should warn the Belgians that uranium was now a military commodity and that selling it to the Germans had security implications for Belgium. You might as well say for all of Europe. Or all the world.

Szilard decided Albert Einstein was the ideal messenger to deliver this news, since Einstein was on friendly terms with the Belgian royal family, and Szilard knew him from their earlier work together in Germany. So in July 1939, Szilard and Wigner drove out to the house on Long Island where Einstein was spending the summer. They brought him up to speed on the latest developments in fission research and laid out the possibility of an atomic bomb. Einstein exclaimed, "I hadn't even thought of that!"

The three of them together wrote up a letter in German, addressed to the Belgian ambassador in Washington and signed by Einstein, relaying the warning. They also sent a letter to the US State Department explaining what they were doing, lest the American government think these foreign scientists were up to no good.

That left the problem of the US government's tepid response. Through a mutual friend, Szilard was able to get a meeting with Alexander Sachs, a Jewish immigrant from what was then the Russian Empire—how many times have I introduced someone that way on this podcast?—who had come to America as a child, graduated from Columbia and Harvard, and become an economist advising the Roosevelt Administration. Szilard asked Sachs to deliver a letter to President Roosevelt warning of the danger of an atomic bomb. Sachs was sympathetic to Szilard's concerns, but told him that the subject had already come up at the White House, and Enrico Fermi had advised them that an atomic bomb was probably impossible. Sachs said he would be happy to deliver the letter, but it should come from the most famous scientist Szilard could enlist.

Fortunately for Szilard, he had an in with the most famous scientist in the world. He went back out to Long Island in August, accompanied this time by Edward Teller, another expatriate Hungarian, and the three of them composed a second letter in German, this one addressed to the President of the United States. Szilard brought the letter back to Columbia and dictated an English translation to a stenographer in the physics department. The stenographer later said that as Szilard dictated to her this message about a powerful new kind of bomb, she thought she was working for a nut, and when he told her to close the letter with "Yours truly, Albert Einstein," she was sure of it.

In the letter, Einstein warned of the German research, the embargo on Czechoslovakian uranium, and of the possibility of a powerful new type of bomb. At this time, even the "optimists," if that is the right word, the optimists believed that an atom bomb might weigh several tons, too big to be dropped from an airplane, although the letter noted that it could still be carried into a port by ship and destroy the entire city.

Once the English version was drafted, Szilard mailed it to Einstein to sign and return, then handed it off to Sachs, who asked for an appointment with the President.

Then the Second World War broke out, and appointments with the President were suddenly very difficult to get. Sachs couldn't get into the White House until October 11. When he met with the President, he wanted to make sure Roosevelt got the message and didn't just set Einstein's letter aside, so he read the letter aloud, then read a second letter from Szilard, then described his own concerns.

He may have gone too far. Instead of engaging Roosevelt's interest, Sachs put him off. Roosevelt ended the discussion by saying that US government involvement in nuclear fission research would be premature. Still, Roosevelt invited Sachs back to the White House for breakfast the following morning.

Sachs spent that night pacing his hotel room, trying to think of a way to convince Roosevelt to take action. When morning came and Sachs returned to the White House, he found Roosevelt at the breakfast table. When Sachs approached, Roosevelt teased him, asking what bright idea he had now, and how long would it take to explain. Sachs replied that he wanted to tell Roosevelt a story, and proceeded to relate how the American inventor Robert Fulton had tried to persuade Napoleon to build a fleet of steamships, which could be used to ferry an army across the English Channel and. Napoleon dismissed the suggestion and sent Fulton away. Sachs invited the President to imagine how different European history might have been, had Napoleon listened.

Roosevelt sent for a bottle of French brandy. A particular bottle, one that had been bottled in Napoleon's time, and had been in the Roosevelt family for decades. Roosevelt had a servant open the bottle and pour out a glass for him and for Sachs. Roosevelt toasted Sachs and said, "Alex, what you are after is to see that the Nazis don't blow us up?"

"Precisely," Sachs replied.

Roosevelt sent for his military attaché, Brigadier General Edwin Watson, showed him Einstein's letter, and said, "This requires action."

[music: *eDream*]

The third irony of this time is that, although in some sense, fate dropped the atom bomb into Nazi Germany's lap, the Nazis were unable to take advantage of this historic windfall. They were betrayed by the very thing that made them Nazis: their narrow, rigid, and increasingly vicious ideology.

Their warped beliefs led the Nazis to dismiss the very scientific breakthroughs that made atomic power possible, and to persecute the scientists who were making them. Those scientists migrated to countries where the intellectual atmosphere was freer, taking with them their expertise and their insights, kickstarting British and American research in the field while stunting Germany's.

The story of the birth of atomic energy is also an object lesson in the value of intellectual freedom. A society that allows its thinkers to explore unconventional ideas and welcomes the outcasts from more repressive lands is strengthened by its tolerance. Conversely, a society that limits its citizens' right to think is cutting its own throat.

There is something comforting in the thought that a repressive society inevitably plants the seeds of its own downfall. But don't be too comforted. History doesn't guarantee that a repressive society will fall as quickly as Nazi Germany did, and even Nazi Germany, which only lasted twelve years, did an immense amount of harm in that brief time.

What Bronowski called "monstrous certainty" is inherently destructive and inherently murderous. Anyone who claims that their own ideas, the thoughts that occur within the confines of their own minds, are more important than your humanity, are implicitly embracing the corollary, that they are justified in ending your life in order to protect and perpetuate their idea. History shows where that leads.

I'm going to give Jacob Bronowski the last word, powerful words he spoke while standing at Auschwitz:

This is the concentration camp and crematorium at Auschwitz. This is where people were turned into numbers. Into this pond were flushed the ashes of some four million people. And that was not done by gas. It was done by arrogance, it was done by dogma, it was done by ignorance. When people believe that they have absolute knowledge, with no test in reality, this is how they behave. This is what men do when they aspire to the knowledge of gods.

We'll have to stop there for today. I thank you for listening. This is a special Christmas episode, which is meant as my gift to you, my listeners. I recognize that many of you do not celebrate Christmas, but whether you do or not, I hope you enjoyed this episode, and I wish you and those you care about health and happiness in this season and in the coming year.

And I hope you'll join me next week, here on the *History of the Twentieth Century,* as we set aside the looming catastrophe in Europe for the next two episodes and take a look at the radio boom in the United States, which revolutionized popular entertainment and turned advertising into big business. And Now, A Word from Our Sponsor, next week, here, on *The History of the Twentieth Century.*

Oh, and one more thing. Otto Hahn won a Nobel Prize for his work on uranium fission. Strangely enough, his colleague Fritz Strassmann, who worked with him, was not included in the award. Neither were Lise Meitner or Otto Frisch, though it was they who came up with the correct interpretation for Hahn's and Strassmann's results.

Otto Hahn received the news of his Nobel Prize while he was in Allied custody at the end of the Second World War. Hahn and Strassmann, though they were opposed to the Nazis, remained in Germany and continued their research during the war years. Strassmann and his family even offered a Jewish woman refuge in their apartment, an action taken at great personal risk.

Lise Meitner came to regret that she had worked in Nazi-ruled Germany for as long as she had and criticized Hahn and Strassmann for staying in Germany, although they remained friends after the war. Meitner received many scientific accolades over her life. Albert Einstein even called her "the German Marie Curie," but she was never awarded the most prestigious of them all, the Nobel Prize, despite being nominated 48 times by some of the biggest names in physics, including Otto Hahn.

Otto Frisch came to the United States to work on the American atomic bomb project. He invited his aunt Lise to come with him, but she refused as a matter of principle to work on an atomic bomb. She lived in Sweden for the rest of her life and remained friends with Otto Hahn. They both died in 1968, just weeks apart. Both were 89 years old. Fritz Strassmann died in 1980, at the age of 78.

Sigmund Freud's works were also prominent among those destroyed in Nazi book burnings. After the *Anschluss,* Freud left Vienna, where he had lived his entire adult life, and was able to move to London. Freud developed oral cancer, and by September 1939, was sufficiently in pain to be administered euthanasia, at his own request, by his physician, friend, and fellow refugee from Nazism, Max Schur. Freud was 83 years old.

Arnold Schönberg was on vacation in France in 1933, when Hitler became chancellor. He decided not to return to Germany, where he had been teaching music composition. After being unable to relocate to Britain, he came to the United States, where he took a teaching position at Boston University, then later at the University of Southern California and the University of California, Los Angeles. His music was banned as "degenerate art" in Germany and Austria. He became a US citizen in 1941, and lived the rest of his life in California. He died in 1951, at the age of 86.

Kurt Gödel's Austrian citizenship became German citizenship following the *Anschluss.* Though he was not Jewish himself, his associations with Jewish academics made him suspect and he was unable to secure an academic position. After the Second World War began, he was at risk for conscription, so he and his wife traveled to the United States, where he was offered a position at the Institute for Advanced Study in Princeton, alongside Albert Einstein. Gödel and Einstein became close friends. They were known to take long walks together, during which they discussed whatever an Einstein and a Gödel might discuss between themselves. Einstein once said the best part of being at the Institute was "the privilege of walking home with Gödel."

Albert Einstein became a US citizen in 1940. In 1947, it was Gödel's turn to take the required citizenship examination. Einstein accompanied him to the test, and along the way, Gödel mentioned to him that in studying the US Constitution for the test, he had discovered a flaw that would allow the US to degenerate into a dictatorship. Einstein suggested to Gödel that he not bring this up during the citizenship examination. He did anyway, but the examiner did not pursue the subject and Gödel was awarded US citizenship.

This purported flaw in the US Constitution has come to be known as "Gödel's loophole," although it doesn't appear Gödel ever explained to anyone what it was. Maybe it was for the best that he kept it to himself.

Kurt Gödel died in 1978, at the age of 71.

[music: Closing Theme]