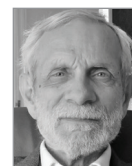




Frédéric Joliot-Curie. (Photo by CTK/Alamy Stock Photo.)

Bill Sweet is an adjunct professor at New York University's Tandon School of Engineering in Brooklyn. He teaches courses on climate, energy, and alternative energy technologies, always with an emphasis on writing skills.



France's Oppenheimer

William Sweet

Frédéric Joliot-Curie was one of the first to conceive of the nuclear chain reaction. But the ardent advocate of nuclear disarmament paid a high price for his political convictions.

When Albert Einstein wrote to President Franklin D. Roosevelt on 2 August 1939 apprising him of the threat that an atomic bomb might be built, he naturally drew attention to work by Leo Szilard, the first person to realize that it might be possible to build the bomb, and Enrico Fermi, who would build the world's first reactor. But the operative second paragraph gives primacy not to them but rather to a French physicist, Frédéric Joliot, a name largely lost to the general US reader.

"In the course of the last four months it has been made probable—through the work of Joliot in France as well as Fermi and Szilard in America—that it may become possible to set up a nuclear chain reaction in a large mass of uranium, by which vast amounts of power and large quantities of new radium-like elements would be generated."

Who was Joliot, and how did he come to be forgotten in the US?

Joliot and his wife, Irène, daughter of Marie Curie and Pierre Curie, came to fame in 1934 with their discovery that radiation can induce a previously stable material to become radioactive—a discovery so important that it was instantly recognized with the 1935 Nobel Prize in Chemistry. That made for a beautiful and unequaled symmetry: Marie and Pierre had discovered natural radioactivity in radium and polonium; Frédéric and Irène found it was possible to invent and fabricate new radioactive elements at will, opening up a world of applications, first of all in nuclear medicine. Joliot naturally drew attention to those applications in his 1935 Nobel address, but he also referred to the possibility of generating a "chain reaction" in radioactive materials.

At the end of the 1930s, on the eve of the outbreak of World War II, Joliot scoped out the technical requirements of a nuclear reactor and filed patents on such a device. At that point, in the estimation of the famed British physicist Patrick Blackett, Joliot's team led the world in thinking about how atomic energy could be harnessed and almost certainly would have built the world's first reactor, had the Nazis not invaded.^{1,2}

At the end of the war and occupation, Joliot personally brought the potential of nuclear energy to the attention of Charles de Gaulle and Raoul Dautry, who had been the armaments minister in 1939–40 and would become France's reconstruction minister after the country was liberated. Meanwhile, under the eyes of the Gestapo, Joliot used his Paris lab to secretly manufacture radios and munitions for the French Maquis guerrilla bands. Although arrested twice, he got himself released both times with the help of an influential German physicist.¹

Immediately after the war, Joliot built France's first nuclear reactor and thus, for better or worse, can be considered the father of the country's atomic program. But because he always

FRANCE'S OPPENHEIMER

strongly opposed the development of nuclear weapons, he was equally a father of the global movement to abolish them.

Joliot was gifted, gutsy, and—not least—good-looking and personable. He had influential friends everywhere. From 1945 to 1950, he would be not only France's top scientist but the country's top science administrator. But at the end of the decade, with the imminent invention of the hydrogen bomb and the French government starting to eye its own atomic bomb development, a kind of McCarthyism took hold in France, and Joliot was stripped of his administrative positions and all policy advising. It is here that his story closely parallels that of J. Robert Oppenheimer's. (For more on Oppenheimer's life, see "Oppenheimer in the *PT* archives," *PHYSICS TODAY* online, 21 July 2023.)

Early years

Joliot was born in 1900 and was the last of his mother's six surviving children. His father was a cloth wholesaler, and later in life, Joliot would sometimes say that experimentalists should be like small-business owners—flexible about means and ends. Enormously good at making things with his own hands, he was a talented experimenter from a young age, and he often turned his mother's kitchen into a veritable chemistry lab.

Upon completing high school and after some initial stumbles, Joliot was admitted to the prestigious *École de Physique et Chimie Industrielles* (now ESPCI Paris), where Marie and Pierre worked. There, he caught the attention of its director of studies, Paul Langevin, who was one of France's leading physicists at the time, and not so incidentally, a one-time lover of Marie Curie. Langevin recommended Joliot to her, and she hired him as her lab assistant, a position in which he proved to be a "ball of fire," she would say. There he met Irène, and they fell in love and were happily married. The two adopted the surname Joliot-Curie, and Irène would be a close collaborator in all their early scientific work.

Starting in 1929, Joliot published a series of papers, sometimes with Irène and sometimes alone, that explored the properties of polonium. It has the useful characteristic of emitting lots of high-energy alpha particles but practically no other radiation.² Typically, when Joliot found that he needed a Geiger counter to pursue the work, he simply built one himself—such an instrument wasn't a standard piece of equipment that could be bought at the time. Similarly, he made a Wilson cloud chamber that enabled him and Irène to observe and photograph the tracks left by certain kinds of nuclear disintegration processes.

The Joliot-Curies figured out by 1931 how to prepare highly radioactive polonium sources. It was a technical achievement and consequential, Blackett observed, because at that time—before the development of large accelerator facilities—strong sources were the essential means with which to study nuclear structure.

In 1932, the Joliot-Curies turned to the study of what happens when boron or beryllium atoms are bombarded with alpha



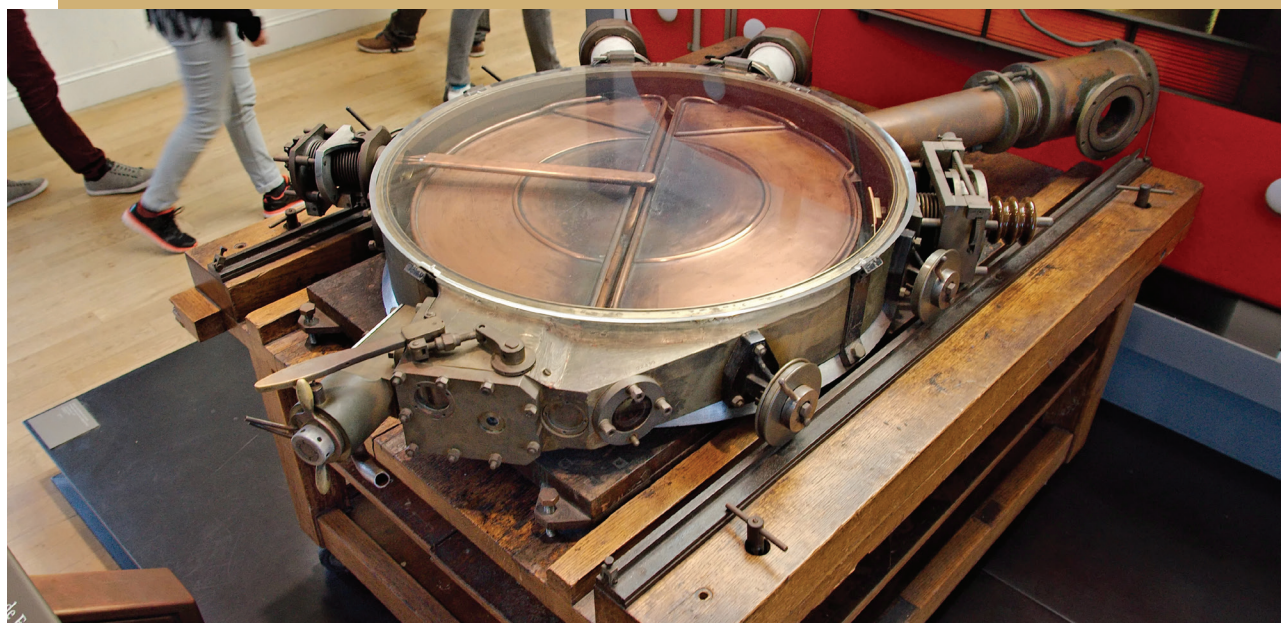
FRÉDÉRIC JOLIOT-CURIE AND IRÈNE JOLIOT-CURIE working in their shared laboratory in 1935. (Photo by Zuri Swimmer/Alamy Stock Photo.)

particles from polonium. They initially misinterpreted the results, leaving it to James Chadwick at the Cavendish Laboratory in the UK to appreciate that they had discovered the long-sought neutron. The existence of such a particle had been postulated well before, but no trace of it had been found before then.

After Caltech physicist Carl Anderson discovered the positron that same year, the Joliot-Curies turned to its study, initially doing experiments to determine whether the atomic nucleus might consist of a neutron and a positron. That work led to the discovery of artificial radioactivity. When investigating what would happen when a thin sheet of aluminum foil was irradiated by polonium, they were astonished to find that the aluminum continued to emit radiation after the source was removed. "It was as if handling a stick of wood could induce it to burst into flower," says historian of science Spencer Weart.³

Without pretense or false modesty, the Joliot-Curies announced their discovery in the 15 January 1934 issue of France's *Comptes Rendus*. An English translation reads: "For the first time it has been possible to make certain atomic nuclei radioactive using an external source. This radioactivity can persist for a measurable time in the absence of the source which excites it."⁴ A month later, in California, Ernest Lawrence would confirm the discovery using his cyclotron, and he and Joliot established what would become a long professional friendship, despite Lawrence's more conservative politics.

Because of that discovery, all kinds of radioactive materials could now be made and applied widely in biology and medicine. Joliot would take note of those applications in his 1935 Nobel lecture, but he also said presciently "that scientists, building up or shattering elements at will, will be able to bring about transmutations of an explosive type, true chemical chain reactions. If such transmutations do succeed in spreading in matter, the enormous liberation of usable energy can be imagined."



THIS CYCLOTRON was used by Frédéric Joliot-Curie and Irène Joliot-Curie in the late 1930s in Paris during the course of their nuclear-physics research. (Photo by Frédéric Bisson/CC BY 2.0.)

Just two years earlier, Szilard had had his famous epiphany on a London street corner in which he envisioned a nuclear chain reaction. And three years later, Otto Hahn, working with Fritz Strassmann in Berlin and with Lise Meitner and Otto Frisch through correspondence, would discover nuclear fission.

France's first nuclear reactor

Following the discovery of fission in 1938, Joliot conducted a quick and clever experiment, using the Wilson cloud chamber he had built, in which he was able to photograph the fragments that resulted from the splitting of uranium and thorium. Shortly thereafter, working with Lew Kowarski and Hans von Halban, the two men who would be his closest collaborators in that period, he examined the technical requirements of a nuclear power reactor. In a handful of patent applications and technical papers written that summer and fall, they explained that the system would comprise some combination of uranium, hydrogen, and oxygen, with cadmium acting as a reactivity poisoner and controller. The reactor would need a fluid or gas to provide cooling and to drive a turbine system.

The three men recognized that to achieve critical mass—the smallest amount of material that could yield a self-sustaining nuclear reaction—it would be necessary to either enrich uranium to boost the fissile uranium-235 fraction in natural uranium or substitute deuterium for hydrogen to make heavy water. They did not recognize that uranium-238 could capture high-energy neutrons and form plutonium, an element that would be discovered only a few years later.

At that point, Szilard sought unsuccessfully to persuade Joliot to refrain from publishing his work. Weart has enumerated several reasons why Joliot decided to publish: “For one thing, Joliot believed strongly in the international fellowship of scientists. . . . For another, if he and his colleagues failed to publish, they might well be eclipsed by those who did. . . . And if they failed to be first to publish discoveries, the French might have trouble getting the money they would need to pursue the development of industrial nuclear energy.” What is more, with private papers about nuclear fission circulating widely, it was scarcely likely that Germany and the Soviet Union would remain unaware of what was going on. (See the article by Weart, *PHYSICS TODAY*, February 1976, page 23.)

When World War II broke out, Joliot and his colleagues—having recognized the key role that heavy water might play in harnessing nuclear energy—focused on the strategic importance that the world’s only existing supply of heavy water might play.⁵ At that point, the sole facility in the world that produced heavy water was Norsk Hydro’s plant in Norway, which supplied it to scientists for research experiments. The story of how Norwegian commandos, acting on British intelligence, destroyed the plant when the Nazis invaded is one of the war’s rather well-known tales. (It has been dramatized on film, and in Norway, it has been sanctified as one of the most glorious episodes of the war.) What is less well known is that Norsk Hydro also had a stock of heavy water it had already produced, and that alarmed the French.

In a confidential memo to French armaments minister Dautry, Joliot recommended that France immediately buy 400 kilograms of uranium metal from the US for experimental

FRANCE'S OPPENHEIMER

purposes and obtain Norway's 200 kilograms of heavy water. He explained: "A mixture suitably made up of uranium and deuterium presents in the present state of our knowledge all the conditions favourable for the development of chain reactions, etc., and consequently for the huge release of atomic energy."⁶

A French lieutenant, Jacques Allier, was dispatched to Norway to arrange for the stock to be "borrowed." It was then transported to France in 26 5-liter canisters, which were specially manufactured by a Norwegian craftsman to camouflage their contents, and was received in Paris on 26 March 1940.

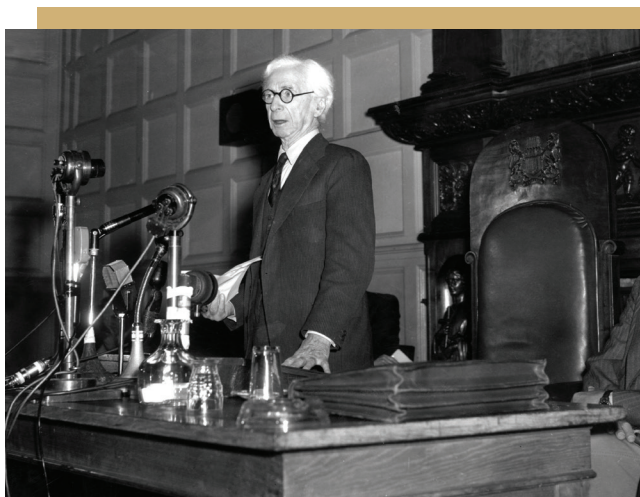
After Germany's invasion that spring, Joliot had the canisters transferred to Clermont-Ferrand in central France, where they were stored in a bank vault and then in a prison. But when that, too, proved unsafe, given that the Germans had assumed effective control of the whole country, Joliot had Kowarski and Halban take the stock to the UK. They left from Bordeaux and arrived at Falmouth on 21 June, and Joliot instructed them to proceed with the construction of a nuclear reactor.

Had the war not intervened, might Joliot have been the first to demonstrate a self-sustaining nuclear chain reaction, as Blackett suggested? It is a complicated question, and Blackett's hindsight assessment is speculative by definition. On the one hand, the 1939 patent filings by Joliot, Kowarski, and Halban seem to contain nothing resembling a diagram of an actual reactor. The filings are entirely conceptual. On the other hand—and it's a big other hand—Joliot always was incredibly good at making things. So perhaps he would have succeeded.

When Germany invaded France, Joliot chose to stay in Paris. Perhaps he wanted French work in atomic physics to proceed at a high level so that the country could be well positioned in the postwar period. But as a fervent patriot who always had been political, he also wanted to contribute to France's liberation. Evidently, because of his fame and prestige, he was made the titular head of the French Resistance, and in that capacity, Joliot made his Paris lab a munitions factory.

The Germans were not completely oblivious to his activities. The Gestapo twice took him into custody, but both times he was sprung at the behest of an influential German physicist, Wolfgang Gentner. When Joliot had built his first Geiger counter 10 years earlier, he had sought Gentner's advice.⁷ A close professional friendship developed, and as luck would have it, Gentner was dispatched to Paris during the occupation to keep an eye on French scientists. He negotiated an agreement that allowed Joliot to keep his lab running, provided that he conduct research with strictly peaceful applications, and it was Gentner who saved Joliot when his lab was caught doing the opposite.

Soon after the liberation of France, Joliot reminded future president de Gaulle and future reconstruction minister Dautry about atomic energy's industrial potential. Starting in 1947, Joliot would supervise the design and construction of France's first reactor, Zoé, in the Paris suburb Fort de Châtillon. (Zoé was an acronym for zero power, uranium oxide, and



BERTRAND RUSSELL issued on 9 July 1955 the Russell–Einstein Manifesto, which highlighted the dangers of nuclear weapons. The document was cosigned by several prominent scientists, including Frédéric Joliot-Curie, who had proposed the appeal to Russell. (Photo from the Smith Archive/Alamy Stock Photo.)

eau lourde, or "heavy water.") Kowarski was a project manager, having already built the first non-US heavy-water reactor in Canada during the war as part of the Manhattan Project. Zoé went critical on 15 December 1948. The day after, France's High Commission for Nuclear Energy said that a long-term program had begun, and the next step would be the construction of two heavy-water reactors.

In the years that followed, France initiated the world's most ambitious program of reactor construction, but not by the route Joliot and the commission had proposed. Like the UK in the 1950s, it developed a gas-cooled graphite reactor. In the 1960s, France adopted a light-water reactor whose design was overseen by US Navy admiral Hyman Rickover. But it was Joliot who got the ball rolling. With Halban and Kowarski, he fathered the heavy-water reactor and France's *tout-nucléaire* ("all-nuclear") energy program.

Changing political winds

From 1945 to 1950, Joliot was France's most prestigious scientist and the country's top science administrator. He was head of the CNRS, France's counterpart to the US's NSF. He was the leading scientist at the newly created Atomic Energy Commission. He spearheaded the construction of the Saclay research laboratories, France's counterpart to US national labs. He was an adviser and board member of many organizations. He had the ear of everybody at the top, and his counsel in all things nuclear was always sought.

But at the end of the 1940s, with Cold War clouds gathering, Joliot came under attack, first in the US and then in France. It is here that his life begins to closely parallel Oppenheimer's, but with a twist: Oppenheimer was accused of having Communist associations, whereas Joliot actually was a Communist.

During the war, as president of the Resistance, Joliot had joined the Communist Party, which in France, unlike in the US, had a mass following. Presumably, that was partly because French Communists formed the backbone of the Resistance. But his joining was a small step, given his sympathies.

Working at a steel mill factory in Luxembourg as a student, Joliot rubbed shoulders with workers from France, Germany, and Belgium, and he became concerned about issues of income distribution and wealth. His father had been a Communard, a supporter of the revolutionary Commune of Paris in 1871, and his mentor Langevin had been a Dreyfusard—a supporter of Alfred Dreyfus, the French officer who had been vilified by France's radical right because he was Jewish. During the Spanish Civil War, Frédéric and Irène had been fervent supporters of the republic. After World War II, with so many French Communists having served in the Maquis guerrilla bands, and with many French people voting for Communist representatives, nobody looked askance at Joliot being a card-carrying member of the party.

The trouble began on 27 December 1948, when *Time* magazine ran an article with a headline calling the Zoé reactor “A Communist’s Atomic Pile.” The *New York Herald* soon chimed in, calling Zoé a “veritable threat.”⁸ Initially, the accusations had little traction in France. “As the Cold War intensified, however,” says historian Gabrielle Hecht, “successive governments found Joliot-Curie’s communist affiliations increasingly embarrassing.”⁹ Another historian, Lawrence Scheinman, has speculated that among policymakers, there probably was an “unarticulated fear that other forms of [US] aid, military or economic, might suffer if France did not remove Joliot-Curie.”¹⁰

In addition, a lobby in France was developing that favored the pursuit of nuclear weapons, analogous to the US lobby that wanted the hydrogen bomb. Joliot had always opposed nuclear weapons. And on 5 April 1950, he gave a speech to a congress of the French Communist Party in which he said that “the imperialists would like to launch a new war against the Soviet Union and the popular [Socialist] democracies.”¹¹ He said that never would Communist scientists support such a war with their knowledge. A few weeks later, on 28 April, Joliot was expelled from policymaking circles.

In a flash, Joliot went from being France’s most influential scientist to being ostracized. Colleagues and friends who had sought him out at conferences now shunned him. Isolated and with little left to lose, Joliot’s political positions became increasingly one sided and myopic. During the opening years of what came to be called the Cold War, he and the organizations that he was affiliated with sat by silently while the Soviet Union took control over all of Eastern Europe. In Joliot’s eyes, the Soviet Union could do no wrong, and the West could do no right. One of Joliot’s biographers has called those years tragic; I prefer to think of them as just sad.

Yet Joliot was not without redeeming qualities. In the early 1950s, he became an outspoken advocate of nuclear disarmament and at times had a real impact. Joliot was instrumental

in the formulation of the 1950 Stockholm Appeal, which called for the absolute ban of nuclear weapons and was the opening salvo in what would become a global nuclear disarmament movement. Like Oppenheimer, he strongly opposed the development of the hydrogen bomb by the US and the Soviet Union.

Following a broadcast by the philosopher Bertrand Russell in 1954, Joliot wrote to Russell and asked whether he would be open to formulating a joint declaration of scientists on the perils of nuclear weapons. Russell said that he would, provided it be nonpartisan and cast no blame. That proposal led to the issuance of the Russell–Einstein Manifesto of 9 July 1955, which Joliot cosigned with 10 other eminent scientists. And yet later that year, the Joliot-Curies were not invited to an Atoms for Peace conference—an important step in the creation of the International Atomic Energy Agency and the Nuclear Non-Proliferation Treaty.

Irène Curie died on 17 March 1956 of leukemia. A scientist friend attributed her death, like Marie’s, to “our occupational disease.” Joliot died of liver disease, possibly from radiation exposure, on 14 August 1958, at the age of 58. He and Irène had always been athletic, skiing in the Alps during winters and swimming in Brittany during summers. But like so many men of his generation, Joliot had been a lifelong chain smoker.

Were Joliot alive today, what would he have to say? No doubt he would be dismayed that Russia has fallen into the hands of a right-wing authoritarian, who brandishes his nuclear arsenal and conducts nuclear combat exercises. He would be equally dismayed that nuclear weapons, far from being beyond the pale, have become more entrenched than ever around the globe. Nine nuclear states, not just two, have nuclear weapons, and Iran is on the way. Still, he might find a glimmer of hope that one nuclear state, South Africa, gave up its arsenal, showing that it is possible to put the genie back in the bottle. Perhaps most of all, Joliot would regret that there are no individuals alive today who, like Einstein and Russell, rise so high above the fray that they can command the world’s attention with an appeal for nuclear sanity.

REFERENCES

1. P. M. S. Blackett, *Biogr. Mem. Fellows R. Soc.* **6**, 86 (1960).
2. S. R. Weart, *Scientists in Power*, Harvard U. Press (1979), p. 41.
3. Ref. 2, p. 45.
4. M. Goldsmith, *Frédéric Joliot-Curie: A Biography*, Lawrence and Wishart (1976), p. 56.
5. Ref. 4, p. 77; P. Biquard, *Frédéric Joliot-Curie: The Man and His Theories*, G. Strachan, trans., Paul S. Eriksson (1966).
6. Ref. 4, p. 79.
7. W. Gentner, interview with C. Weiner, 1971, www.aip.org/history-programs/niels-bohr-library/oral-histories/5080.
8. D. Sloan, *FUSION*, August 1980, pp. 36, 44.
9. G. Hecht, *The Radiance of France: Nuclear Power and National Identity After World War II*, MIT Press (1998), p. 59.
10. L. Scheinman, “The formulation of atomic energy policy in France under the Fourth Republic,” PhD thesis, U. Michigan (1963), p. 79.
11. Cambridge Scientists’ Anti-War Group, “The Case of Professor Frédéric Joliot-Curie,” International Labour and Radical History Pamphlet Collection, Archives and Special Collections, Memorial University of Newfoundland Libraries. 