pointed Professor at the Sorbonne. She retained her laboratory at the Radium Institute. where she pursued the research program initiated by her parents. Frédéric Joliot was appointed Professor at the College de France. He began a second research program on nuclear reactions that eventually led to his becoming the first high commissioner of the Atomic Energy Commission (Commissariat à l’Énergie Atomique, hereafter CEA), upon its foundation in October 1945. His brilliant career, energetically conducted amidst the tensions and competition surrounding World War II, pioneered the general trend within the French scientific community from traditional individualistic research to large research teams in laboratories.

Therefore, it seems important to revise the stereotype of the Joliot-Curies as star scientists. Considering Irène Curie and Frédéric Joliot as distinct figures, this paper will stress the contrast of their characters. It will focus on Irène’s career because hers is a unique case in the history of science: the daughter of a famous Nobelist scientific couple, Marie and Pierre Curie, she was herself a partner in a Nobelist couple. Her life and innovative work are usually described as a brilliant anomaly in the mostly male, conservative scientific community of French physical scientists, a community clinging long to a tradition of experimental physics, while ignoring some of the more recent developments in atomic physics in the interwar period. 3

Without minimizing Irène Joliot-Curie’s outstanding achievements, I would like to suggest that, when placed within the milieu of her family and the broader historical and social context of French science, the life and work of Irène Curie seem not only less anomalous but even, to a certain extent, conformist.

The first section of this essay (Childhood and Family Context), covering Irène Curie’s childhood, emphasizes the importance of her family as a milieu that prompted her choice of career, especially the importance of her widowed mother as a role model. The second part (The Curie Scientific Style), devoted to her scientific achievements, considers the kind of collaboration she had with her husband and their position within the international physics community. The third part (Public and Private Life), which is concerned with Irène Curie’s public life, highlights her success in designing her own style as a woman scientist.

* Childhood and Family Context

Throughout the nineteenth century, when France went through many political upheavals and changes of government, science emerged as one element of stability. Under the supreme control of the French Academy of Sciences, scientific activity revealed a remarkable continuity, exemplified by scientific dynasties such as the Jussieu, a family of natural scientists—Antoine, Bernard, Antoine-Laurent, and Adrien—whose destiny was for nearly a century closely intertwined with the history of an institution, the Muséum d’histoire naturelle, formerly known as the Jardin du Roi. 4 The physics section of the Academy of Sciences continuously had a Becquerel among its members from its creation in 1824 until 1908. The Becquerel dynasty covered three successive generations: Antoine (1788–1878), who did important work on electric batteries; his son Edmond (1820–1891), who joined the Academy in 1863 after doing research on magnetism, electricity, and luminescence; and the grandson Henri, discoverer of uranium rays in 1896 and co-winner of the Nobel Prize in 1903 with Pierre and Marie Curie.

This, the end of one scientific dynasty that influenced nineteenth-century science was the beginning of another illustrious scientific dynasty that deeply influenced twentieth-century science. The Curie family, in turn, had three successive generations who joined the Academy of Sciences: Pierre Curie in 1905, Frédéric Joliot-Curie in 1942, and Pierre Joliot in 1982. Possibly a fourth generation is on its way, since Alain Joliot, who recently finished his Ph.D., seems to have made a promising start in his career in the life sciences.

Yet, in contrast to former scientific dynasties, the Curie-Joliot family was a dynasty of couples: over three generations, the women did not content themselves with the traditional female role of a scientist’s wife, or with taking charge of the social activities related to the operation of scientific patronage. 5 Marie Curie (1867–1934), Irène Joliot-Curie, and Hélène Langevin-Joliot (born 1927) were at least as active as their husbands in scientific research. It must be stressed, however, that none of the female spouses, two of whom were Nobelists, was elected to the male-dominated Academy of Sciences.

Both Irène and Hélène chose to work in the same field as their parents: radioactivity for Irène, who, significantly, took polonium, an element discovered by her mother, as the topic of her early research. (Her doctorate was on particles emitted by polonium.) Moreover, Irène stayed at the Radium Institute, founded by her mother, during her entire career. Her daughter, Hélène Langevin, now works in nuclear physics at the University of Orsay, a department founded by Frédéric Joliot-Curie in the 1950s. (Her brother, Pierre Joliot, chose a related but distinct field, biophysics.)

Both Irène and Hélène married within the “tribe” of the scientific elite, thus consolidating the French tradition of “scientific endogamy,” since intermarriage between scientists’ families was already frequent in early-nineteenth-century Europe. 6 Irène met her husband at the Radium Institute among her mother’s students. He had the same background as her father, having been trained at the Ecole municipale de physique et de chimie industrielle, where Pierre taught. Hélène met her husband inside the inner circle of scientists surrounding the Curie family; she married Michel Langevin, grandson of Paul Langevin (1872–1946), the French physicist.
who had a love affair with her grandmother Marie Curie in 1911. Like her father and grandfather, Hélène’s husband was a physicist.

The Curie family lived in a scientifically stimulating milieu. Pierre and Marie Curie were close friends of Jean Perrin (1870–1944) and Paul Langevin, two leading figures of French physics; Emile Borel (1871–1957), a leading mathematician; and Charles Seignobos, a famous historian. All these families used to spend their summer vacations swimming, sailing, and biking at l’Arcouest, a little fishing port on the Brittany coast, which they jokingly nicknamed “Sorbonne plage.” The children not only shared their summer activities year after year but also studied together in Paris. Instead of attending the state primary school, they were taught at home by their parents. Marie Curie was in charge of teaching physics, Paul Langevin of mathematics, Jean Perrin of chemistry, and Henriette Perrin of history and geography. When she was about twelve years old, Irène went to a private school, the Collège Sévigné. She passed the baccalauréat exams in July 1914, at the age of seventeen, and became a student of chemistry at the Sorbonne. Brought up apart from public schools, Irène never had the apprenticeship of sociability normally provided by the schoolyard. This special education may have determined a striking, dominant feature in her adult life. Irène Joliot-Curie was rather shy and not very talkative. Some collaborators said she often behaved in a clumsy and tactless way and was absolutely unfit for public relations.

Irène never left the niche of the Curie family to venture into an unknown world. It was so obvious to her that she had to follow the same path as her mother that she never contemplated the possibility of choosing a different way of life. Looking back to her childhood, it would not be too difficult for a psychoanalyst to provide some explanation in terms of, say, a “Jocasta complex.”

Irène Curie was born in Paris on September 12, 1897, the same year her mother started her doctoral research on elements emitting uranium-like radiations. As a child she was initially cared for by a nurse and later by her grandfather, Dr. Eugène Curie, who came to live in the house of his son Pierre when he became a widower. Pierre and Marie’s scientific activity reached its peak during Irène’s early childhood. In 1898 they discovered radium, and the following years were devoted to painstaking and exhausting experimental work for testing the elementary nature of radium and polonium. In 1903 the Nobel Prize brought a flood of public attention, with many journalists and visitors at their home. Though tenderly loved by her grandfather, the young Irène could not help but feel lonely, often abandoned by her parents, who spent most of their time with their other child: radium. Jealous of radium, then jealous of her younger and prettier sister, Eve (born in 1904), Irène came to demand exclusive love from her mother, apparently trying to capture her mother’s attention through what is now termed anorexia.

However, after Pierre Curie’s accidental death in 1906, Marie Curie’s depression led to her seeking increasing affection from her eldest daughter. Irène, eventually establishing a mother and daughter collaborative team during World War I for the mobile X-ray units, and later in the laboratory. Following Dr. Eugène Curie’s death in 1910, the Curie family consisted of three women. The two sisters chose contrasting roles. Whereas Irène was inclined to emulate her mother—she was fond of mathematics, swimming, sailing, and trekking, and did not care for pretty clothing—Eve, who was seven years younger than Irène and who felt excluded from the learned conversations between Marie and Irène, chose an alternative model. She became a charming, attractive, talkative child, fond of the piano, who developed a different relationship with her mother, one of mutual protection. When Marie became increasingly blind and fragile in the 1920s, it was Eve who took care of her, in a motherly way.

In contrast, as Irène matured, she gradually took the place of the missing Pierre Curie in her mother’s life as a scientific partner and companion. Though she was only seventeen years old when World War I broke out, she assisted Marie Curie on the northern front with the mobile X-ray units and served as a military nurse until the war’s end.

The Curie Scientific Style

In 1918, shortly after the demobilization, Irène Curie entered the Radium Institute, founded and managed by her mother, as a préparateur. In France, this was a regular position for junior scientists preparing a doctorate with a senior scientist as a patron. Frédéric Joliot occupied the same position when he came to the Radium Institute in 1925, on the recommendation of Paul Langevin. Though she started in the modest position of a beginner in the laboratory, Irène soon became Marie Curie’s favorite assistant. She devoted herself to investigating the fluctuations of alpha rays emitted by polonium and gamma rays emitted by radium, two elements discovered by her parents. Though Irène would later discover new radioactive isotopes as well as new radioactive phenomena, the feeling of continuity in the family circle was so strong that when Eve Curie published an article about Irène in 1936, she described the discovery that prompted her sister’s Nobel Prize in 1935 as the “discovery of artificial radium.”

While reproducing Marie Curie’s model of collaborating with one’s husband, Irène’s career was worlds removed from the difficult conditions encountered by her mother. She never had to work in a poor shelter or live in a miserable student room. Moreover, Irène started her career with a salary of Fr 20,000 given by the government to her powerful patron, her mother. In 1921 she accompanied her mother on her triumphal visit to the United States, traveling in luxurious conditions and being introduced to influential scientific circles. When she married Frédéric Joliot, one of her mother’s top students, in 1926, Irène also received an apartment from her mother.
Moreover, Irène worked in a well-funded, prestigious institution that attracted scientists from all over the world. She entered her career with an already famous last name. As early as 1925, when Irène defended her thesis, a crowd of journalists gathered in front of the Sorbonne. She was perceived to be a future star scientist and a potential Nobel Prize winner, even before she had done any work on her own. Irène, unlike Marie, never had to fight for recognition.

Her comfortable position in her early career, together with the special education she received as a child, made her independent of public opinion. Her self-confidence was so deeply rooted in the family niche that she is said to have been absolutely indifferent to her public image and to all marks of social prestige.

In her "predetermined" career, the main source of surprise came from the side of Frédéric Joliot. Though he belonged to the same little world of the Radium Institute and was also fascinated by Marie Curie, who supervised his early research, his cheerful character contrasted with Irène's. He was as lively, talkative, and charming as she was shy and lofty. He had a remarkable capacity for fantasy and was always seeking to captivate people around him. At first glance, Irène and Frédéric made as odd a couple as Molière's Alceste and Célimène, with a reversal of the male and female roles. Irène could evoke the misanthropic Alceste and Frédéric the charming Célimène. Frédéric also showed great political concern, stimulated by his first "patron" at the Ecole municipale, Paul Langevin. Having broken the excessively close relationship between mother and daughter, Frédéric provided Irène with an equilibrium she could not reach in her own family. There are many signs that she was happier as a wife. When Irène became a mother, she felt much more attached to her children and presumably more dependent on them than Marie Curie had been with regard to her own daughters, until later in life. Irène's closer relationship to her children can be viewed as a feature of her own, one she did not draw from her mother's model. Conceivably, the only domain in which Irène might have pretended to improve upon her brilliant scientist-mother was in her own everyday life as a mother.

The close collaboration between Irène and her husband did not start before 1929, or three years after their marriage, and was aimed at investigating the alpha rays emitted by polonium. To a certain extent, as Noelle Loriot rightly emphasized, the Joliot-Curie couple reproduced the complementarity between Pierre and Marie Curie: Frédéric, much like Pierre Curie, who had built a highly sensitive electrometer that allowed Marie to test very weak radiations, proved an expert in the design of new scientific instruments. In 1931 Frédéric Joliot-Curie built an improved Wilson chamber, an apparatus for visualizing trajectories of ionized particles through a gas saturated with water vapor.

In the early years of the Joliot-Curie collaboration, Irène, scientifically somewhat older and more expert, was undoubtedly the leader: she had already accumulated a great deal of Radium Institute experimental skill. In their collaborative work, Frédéric's clever and hard work on the electrolysis of polonium conducted for his Ph.D research enabled him to define precisely the chemical properties of polonium and to assign it a place after tellurium in the periodic table of chemical elements. He thus became an expert in preparing very thin metallic sheets, which proved very useful in further research on the interaction between matter and radiation.

Radiochemistry required not only the painstaking manual tasks of concentrating, purifying, and crystalizing the active substance, exemplified in Marie Curie's early research on radium, but also a specific skill for making fast and accurate physical measurements in experiments on the interaction between rays and particles. To grow up in the Radium Institute was undeniably a great advantage for Irène, because it provided her with a great deal of tacit knowledge. Over these early years, the Joliot-Curie couple appeared to be a cross-gender mirror of the earlier couple of Pierre and Marie. With her seniority and expertise, Irène acted like Pierre, while the latecomer Frédéric, ambitious as he was, played the role of Marie.

Like Marie and Pierre Curie, Irène and Frédéric Joliot-Curie never acted as a single person. Nevertheless, whatever their contrasting psychological dispositions, they shared a common formative scientific culture, the local subculture of the Radium Institute. In contrast with other leading laboratories studying radioactivity, such as the Cavendish Laboratory in Cambridge, Enrico Fermi's laboratory in Rome, and the laboratory of Otto Hahn and Lise Meitner at the Kaiser Wilhelm Institute in Berlin, the Radium Institute of the 1920s offered a subculture that can be characterized as chemistry oriented. In all these laboratories, scientists performed similar experiments, bombarding various elements with alpha particles, then detecting and identifying the rays or particles emitted. They used different methods, including the scintillation technique, used by Ernest Rutherford after 1908, or the droplet technique, initially designed by Robert Millikan. The latter was displaced by the Wilson chamber and the Geiger-Müller counter in the 1930s.

However, at the Cavendish, the main purpose of Ernest Rutherford and James Chadwick's experiments was to elaborate a theory of the atomic nucleus. In Berlin, at the Kaiser Wilhelm Institute of Chemistry, headed by Otto Hahn, Lise Meitner's work was aimed at clarifying the relationship between alpha and beta rays in order to shape a nuclear theory. Working in close relationship with Max Planck and quantum physicists, Meitner did her best to apply quantum theory to nuclei, and in some cases especially the spectrum of primary electrons—she disagreed with Chadwick's conclusions. Fermi's laboratory in Rome and the Radium Institute in Paris were more concerned with the purification and identification of radioelements than with the theoretical explanation of radioactive phenomena in terms of atomic structure. Physical measurements were one important aspect of the daily work but were used as means for discovering...
new chemical elements. The significance of the local culture of the Radium Institute can be seen in both the successes and missed opportunities of the Joliot-Curies.

Though abstention from whiggism is the prime commandment of the historian of science, taking a retrospective view of a period is sometimes convenient to emphasize contrasts in scientific styles. Among the above-mentioned leading teams working on radioactivity in the 1930s, the Joliot-Curies couple probably had the highest potential for experimental tacit knowledge. Their ability culminated in the difficult and hazardous art of preparing strong sources of polonium through electrolysis or thermal volatilization. But they lacked the theoretical background that proved to be indispensable for the identification of particles or rays emitted during experiments. Neither Irène nor Frédéric was ready to grasp the theoretical interpretation of the experimental data they had described. Thus the Joliot-Curies paved the way for but missed the discovery of the neutron.

In 1930 two German physicists, Walter Bothe and Herbert Becker, described a new penetrating radiation resulting from the bombardment of a light element such as lithium with alpha rays emitted by polonium, which they identified as gamma or electromagnetic rays. Irène and Frédéric studied the effects of the Bothe and Becker radiation penetrating through matter with a Wilson chamber, the window of which had been covered by a very thin sheet of aluminum. Irène and Frédéric observed a striking phenomenon: when paraffin wax, a substance rich in hydrogen, was exposed to the penetrating radiation, protons (i.e., hydrogen nuclei) were emitted with a high velocity. They concluded that, unlike gamma rays, the penetrating radiation was able to eject nuclei of light atoms. Chadwick (1891–1974), who reproduced the Joliot-Curies’ experiments in the Cavendish Laboratory, identified a new particle, the neutron, in the penetrating radiation, with a mass nearly equal to the mass of the proton but which was not visible in the Wilson chamber because it was electrically uncharged.

Far from being dispirited, the Joliot-Curies turned to experimental studies of neutrons and were able to determine their mass and their velocity at emission. They proved that the penetrating radiation contained not only neutrons but also gamma rays capable of creating light particles with nearly the same mass as electrons but running back toward the emitting source in a magnetic field. They concluded that they had factual evidence for the positive electrons, or positrons, recently predicted by Paul Dirac on a theoretical basis and just discovered in cosmic rays. In October 1933 the Joliot-Curies reported their results at the Seventh Solvay Conference in Brussels and ventured a bold explanation: the emission of a positive electron, Irène declared, was the result of an induced transmutation related to the creation of a neutrino. Their paper was immediately criticized by Meitner, who raised serious objections about the Joliot-Curies’ experimental results, objections that left them disarmed.

Back from Brussels, Irène and Frédéric resumed their experiments, and on January 11, 1934, as they were bombarding a thin aluminum sheet placed over the window of a Wilson chamber with alpha particles, they were surprised to observe that the emission of positive electrons did not stop when the removal of the source stopped the neutrons’ flow. The emission of positive electrons lasted a few minutes and decreased in a way suggesting a radioactive phenomenon. Their experimental skill in radiochemistry was manifest in the fact that they were able to identify an isotope of phosphorus, with a half-life of only three minutes and fifteen seconds, generated by the transmutation of aluminum atoms.

It was “the first atomic nucleus created by man,” as Frédéric Joliot announced proudly before relatives and friends, whom they had immediately called to see their experiment. In 1935 they were awarded the Nobel Prize in chemistry, the third Nobel Prize given to the Curie family. Whereas at the Nobel reception in Stockholm in 1905, only Pierre Curie delivered the address, with Marie sitting silently at his side, in 1935 the Nobel lecture was delivered by both laureates: Irène summarized the process of discovery while Frédéric described the chemical identification of the artificial isotope.

With the Nobel Prize came academic positions that not only put an end to their spousal collaboration but came to emphasize contrasting paths for Irène and Frédéric. Gradually, Irène adopted the more conventional female role of a brilliant “second,” while Frédéric launched a new career that was to make him one of the most influential and powerful scientists in France.18

In 1937 Frédéric Joliot was offered a chair at the Collège de France and was given the facilities for equipping three laboratories with all the modern and heavy instruments required for the study of nuclear physics. While Irène continued her investigations with alpha rays emitted by small quantities of polonium, Frédéric had a cyclotron in his laboratory at the Collège de France that could produce as many alpha rays as one-hundred kilograms of radium. His laboratory at Arcueil had inherited the 1.2-million-volt Van de Graaff generator displayed at the Palais de la Découverte on the occasion of the International Exhibition held in Paris in 1937. For his third laboratory of “atomic synthesis” at Ivry-sur-Seine, near Paris, Frédéric ordered a cyclotron with a 2-million-volt generator. With two young collaborators from among the émigré scientists in Paris, Hans Halban from Austria and Lev Kowarski from Russia, Frédéric Joliot set up a new research program on the effects of neutrons bombarding uranium nuclei.

Whereas Frédéric Joliot escaped the Curie’s niche, Irène stayed at the Radium Institute. Like her mother, she got a chair at the Sorbonne in 1937. Also like her mother, who published a treatise on radioactivity in the early 1920s, she published a textbook entitled Les radioéléments naturels: Propriétés chimiques, préparation, dosage (Paris, 1946). But unlike her mother, she did not become the director of the Radium Institute. Until 1946 it was André Debierne, Marie Curie’s former collaborator and the discoverer of actinium in 1899, who managed the Institute founded by Marie Curie.
Thus Irène, like Fermi, who also searched for transuranic elements, was prepared for but missed the discovery of nuclear fission. Bertrand Goldschmidt, who was then Irène’s young assistant at the Radium Institute, remembered Frédéric’s bitter remark that “had he collaborated with Irène, they would have discovered nuclear fission before the German team.” In fact, the German team was dismantled in 1938 by Meitner’s exile, but she was still able to grasp the theoretical meaning of the experiments performed by her former collaborators. Nevertheless, Meitner also missed one discovery. After identifying the isotope U-239, formed by the capture of a neutron in U-238, she noticed a very weak radiation that was later identified as neptunium by Edwin Macmillan. If we recall that a few years earlier the Joliot-Curie couple had missed the discovery of the neutron, it becomes clear that missing or not missing a discovery is less dependent on the abilities of a creative couple than on the whole research program and local culture of the institution where they are working. Thus, Frédéric Joliot’s bitter remark mainly betrays his increasing self-confidence in his own role as Irène’s indispensable collaborator.

Following his own path, Frédéric Joliot became the French leader in nuclear physics when he set up a nuclear chain reaction with his collaborators in 1939. After World War II, he was appointed scientific director of the Atomic Energy Commission (CEA), while Irène contented herself with the subordinate position of head of CEA’s chemistry section. Increasingly, she came to play the more traditional role of a female spouse working in the shadow of her brilliant and powerful husband.

How are we to explain such a reversal of power in the Joliot-Curie couple? In order to understand Irène Joliot-Curie’s transformation from a senior partner in a Nobelist couple into a modest wife, one needs to consider now the balance between her public and private life.

Public and Private Life

Unlike Marie Curie, Irène accepted public political offices on several occasions. After her mother’s death in 1934, she joined the Comité de vigilance des intellectuels antifascistes and wrote a number of papers on the social role of women in fighting for equal status in professional activities. Under the Front populaire, the socialist government elected in 1936, she became the first minister of research and, indeed, the first woman minister in France. However, she resigned after two months, and the position was given to Jean Perrin, a 1926 Nobelist physicist. Why did she accept this official position, and then resign so quickly? Conceivably she accepted this offer in the heyday of great enthusiasm among the socialist scientists who had helped to campaign for the Front populaire. Above all, she seemed motivated by the hope of convincing women that they could reach the highest public responsibilities. But the gap between the feminist symbol and the daily duties of the ministry proved too large for her. She