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Marie Skłodowska Curie

November 7, 1867–July 4, 1934

PHYSICIST AND RADIOCHEMIST

Nobel Prize in Physics 1903
Nobel Prize in Chemistry 1911

"HUSBAND STEALER! Get the foreign woman out!" The sound of shouts and catcalls filled Marie Curie's home. A stone struck the house. The crowd was growing larger and more hostile. Inside, Marie Curie and her seven-year-old daughter Ève huddled white-faced and silent.

For days, the Parisian tabloids had been filled with the Polish woman's scandal: "The Vestal Virgin of Radium" had stolen a French mother's husband. Curie had been maintained like "a concubine in a conjugal domicile.... The fire of radium had lit a flame in the heart of a scientist, and the scientist's wife and children [were] now in tears."

Reporters, editors, and her accused lover fought duels; the French Cabinet deliberated; and the University of Paris tried to get Curie to resign her professorship and return to Poland. In the midst of the crisis, Curie collapsed, contemplated suicide—and won her second Nobel Prize.

At the time, Marie Curie was the world's most famous scientist, a household word, a saintly icon, and an easy target. The first woman professor in France, she had discovered radium, the world's first hope for cancer patients. She was the physicist and chemist who turned the attention of the scientific world to radioactivity and proved that the atom was not inert, indivisible, or solid. For sixty-one years, she was the only person who had won two Nobel Prizes for science.

An intensely private woman, she hid deep emotions behind a composed façade. Longing for a simple family life and freedom to work in her laboratory, she disliked distractions and disturbances. When fame and feelings intruded, they threatened the settled pattern of her existence. Only later did she learn to contain the

passions that had almost destroyed her and to use her unsought celebrity to serve science.

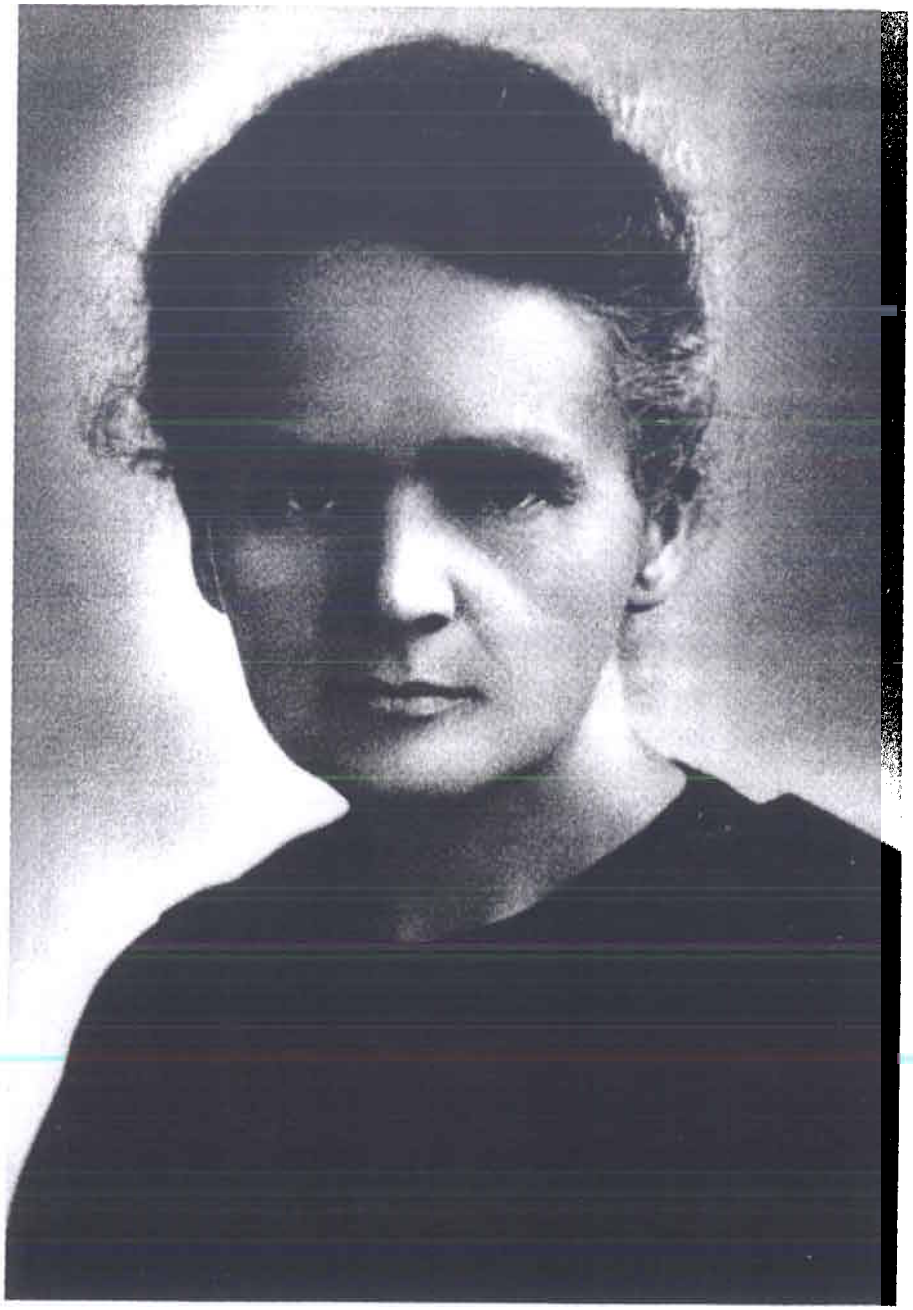
She was born Marya Skłodowska in Warsaw, Poland, in 1867, just after the American Civil War. Called Manya as a child, she changed her name to its French form, "Marie," as a student in France. Her childhood was often tense and unhappy. Russia and Germany had divided Poland between them and were trying to destroy every vestige of Polish nationalism and culture. As Chancellor Otto von Bismarck of Prussia wrote, "Hit the Poles till they despair of their very lives. I have every sympathy for their position, but if we are to survive, our only course is to exterminate them." In Tsarist Poland, Marie Curie learned early that expressing her emotions could be dangerous.

Both her parents, Valdislav and Bronisława Skłodowski, were teachers. Vladislav taught high school physics and mathematics, and although Bronislawa gave birth to five children in eight years and had tuberculosis, she was the full-time director of a private school for girls. She quit her job only after the birth of Marie, her last child. Bad investments and medical bills had cost the family their savings, so they lived in Bronislawa's boarding school. Her babies were born literally within earshot of her paying customers. Life without privacy required silence and self-control, and Marie grew up hating loud voices, commotion, theatrics, and any display of emotion.

Although they held themselves tightly in check, the Skłodowskis were a passionate family of strong convictions. Marie's mother was an extremely devout Roman Catholic, the entire family was intensely patriotic, and they all believed fervently in education. "My father and mother worshiped their profession in the highest degree," Marie recalled later. The children were expected to learn to read before they entered school. When Marie was four years old, she quizzed her older sister Bronya on her letters. Impatiently Marie grabbed the book and began reading it aloud. The family became so excited that Marie burst into tears and apologized for being able to read.

By the time Marie was eleven years old, her oldest sister had died of typhus and her mother of tuberculosis. Hoping to prevent the spread of her disease, Madame Skłodowska had never kissed or fondled her youngest child. Marie, in turn, had idolized her mother without understanding her aloofness. When she died, Marie fell into a profound depression and concluded that God did not exist.

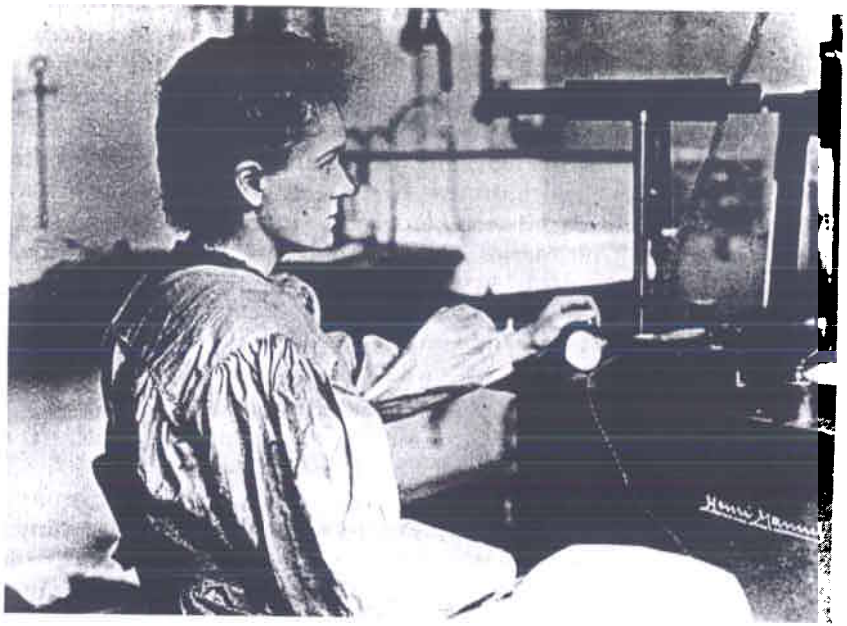
At school, Marie studied in an atmosphere of political intimidation and oppression. The Russians ran Polish schools like police states. Polish teachers were fired and children punished for speaking their own language. As Russians took over Polish teaching positions, Marie's father moved from job to job and apartment to apartment,



Marie Curie, 1913.

Marie Curie with her daughter, Ève (left), and Irène (right), in 1908.

Pierre and Marie Curie in front of their house at Sceaux, 1895.



Marie Skłodowska-Curie in her laboratory.

each smaller than the last. They became so poor that her father took in student boarders for tutoring. Eventually, the family became so crowded that Marie slept on a sofa in the dining room and rose early each morning to clear the room for the boarders' breakfast.

Despite such distractions, Marie was the brightest student in her class, the one chosen to recite in Russian whenever the government inspector made his rounds. Only ten years old, she was responsible for fooling the government into thinking that her school taught Russian culture in Russian, instead of Polish culture in Polish. Marie performed perfectly, but she was so tense that, when the inspector left, she burst into tears. She remained nervous about public speaking for the rest of her life.

In secondary school, Russian professors treated their Polish pupils like enemies. "The moral atmosphere was altogether unbearable," she protested years later. Students were constantly spied upon. One of her brother's friends was hanged for political activities. It is not surprising that schools became centers of Polish nationalism and organized resistance. Education became a patriotic duty and a moral imperative.

Responsibility for preserving Polish culture fell—not on Polish soldiers—but on young middle-class Polish women like Marie. Fol-

lowing the collapse of the last Polish uprising in 1863, a group of Warsaw intellectuals called the Positivists argued that force alone could not defeat Russia. The Positivists campaigned for women's emancipation and education; science; toleration of the Jews; abolition of class distinctions; reform of the Polish Roman Catholic Church; and education for the peasants. Women formed the backbone of the Positivist movement and founded the clandestine Flying University, where anyone could attend secret lectures in return for teaching one. As Marie put it, "You cannot hope to build a better world without improving the individual." A Positivist poem, "Forward Through Work," declared:

> The strains of the harp are not for you....
> Neither saber, nor spear, nor arrow.
> What you need is unremitting toil,
> The food of the mind, the bread of the soul.

Marie Skłodowska's passionate commitment to hard work, learning, and science had its roots in Poland's dream for nationhood.

At the age of fifteen, Marie graduated first in her class in every subject. The strain had been enormous. In 1883, she collapsed in the first of several physical breakdowns she suffered throughout her life. Her father arranged for her to take the year off, visiting relatives in the countryside and enjoying herself. After dancing all night, she declared, "All I can say is that maybe never again, never in my whole life, will I have such fun."

After a year of pleasure, Marie had to start supporting herself—and her older sister Bronya. Their brother was a student at the University of Warsaw, but the Russian government prohibited women from attending any university within its empire. So Bronya and Marie made a pact: Marie would help support Bronya through medical school in Paris, and then Bronya would help pay Marie's way.

Few jobs were open to middle-class women, so Marie spent the next six years (from September 1885 to September 1891) as a governess. She was little more than a servant in a wealthy home. For three and a half of those years, she lived with the Zorawski family sixty miles from Warsaw. She tutored two of the Zorawski children seven hours a day and was at the family's beck and call the remainder of the time. With the father's approval, she also taught local peasant children to read and write, an illegal activity for which she could have been severely punished. She used every moment of her precious free time for study. To help, her father tutored her in mathematics in his letters. Zorawski permitted her to use the technical library in his sugar beet factory, and a factory chemist gave her twenty chemistry lessons.

That summer, the Zorawski's eldest son vacationed at home. Kazimierz was not only handsome and dashing, he was also studying mathematics at the University of Warsaw. Predictably, he and Marie fell in love. Appalled that their son and heir would consider marrying a mere governess, the Zorawskis forbade the engagement. Trapped, Marie stayed at the Zorawskis for two and a half more years because Bronya needed money in Paris. Writing of her anguish, Marie confessed, "Creatures who feel as keenly as I do...have to dissimulate it as much as possible.... I would give half my life to be independent again, to have my own home." Marie did not give up hope of marrying Kazimierz until she was almost twenty-four years old.

In 1891, Marie finally left for Paris with forty rubles in her purse, a trunk, and a camp chair to sit on in the fourth-class train car.

Although she would live the rest of her life in France and became famous under her French name "Marie Curie," she remained passionately involved in Polish affairs. She donated money to the Russian uprising against the hated Tsars in 1905 and hired Polish nursemaids to teach her children Polish. After World War I, she raised money for a Polish radium institute and trained Polish scientists.

Decades later, the French were still not reconciled to their heroine's Polish origins. For the one-hundredth-anniversary celebration of Marie Curie's birth in 1967, French government officials tried to find a photograph that would not make Curie look "so Polish." They also wanted to use only her French name. At the insistence of the Polish government and her French grandchildren, anniversary posters called her Marie Curie-Skłodowska.

For Poles, France represented the glories of cultural and political freedom. The Latin Quarter, the student section of Paris, was the intellectual heart of Europe in the 1890s. At its center was the University of Paris, one of the few universities in Europe that admitted women. Twelve thousand men and a handful of women attended lectures there. French cultural life thrived with post-Impressionist painters, Verdi's operas, the Eiffel Tower, broad boulevards designed by Baron Haussmann, electric street lighting, and automobiles. Politically, the Republic occupied the center between the right-wing nobility and the left-wing workers. Underneath the glittering veneer, however, unemployment was high, anti-Semitism was rife, and Protestants were unpopular. And scientifically, France was conservative and behind the times.

When Marie Curie enrolled in the University of Paris on Novem-

ber 5, 1891, she had been out of school for eight years. Her French was inadequate, and she had studied less math and science than any French high school graduate. Although she could have lived with her sister Bronya in the midst of a large community of Polish political émigrés, she chose to stay by herself. Poor like most other students, she rented a sixth-floor garret room and subsisted on bread with occasional eggs, fruit, and cups of hot chocolate.

She delighted in what her family jokingly called her "heroic period." She had space of her own, privacy, independence, and as much time as she wanted to study. She was enjoying science the way other people love music—for the delight and profound enjoyment that it gave her. As she recalled later, "This life, painful from certain points of view, had, for all that, a real charm for me. It gave me a very precious sense of liberty and independence."

Her heroic period lasted only two years. In 1893, she won a Polish fellowship of six hundred rubles a year. She also earned the equivalent of a master's degree in physics and scored first in her class. The following year, she earned a similar degree in mathematics and placed second.

One of the world's great love stories began in 1894 when Marie Skłodowska met Pierre Curie. Curie was the laboratory director of the Municipal School of Industrial Physics and Chemistry in Paris. At thirty-five, he was already an important physicist specializing in crystals and magnetic materials. He and his brother Jacques had discovered piezoelectricity, the electricity generated by squeezing certain crystals, like quartz. Such crystals are used today in microphones, broadcasting electronics, stereo systems, and wristwatches.

When Marie Skłodowska first saw Pierre Curie, he was silhouetted romantically against the light of a french door. His auburn crew cut, limpid eyes, grave smile, and simple manners instantly reassured her. His conversation about physics and social issues fascinated her. On his part, Pierre Curie saw a Slavic beauty, much in vogue at the time, with curly blond hair, gray eyes, wide cheekbones, and broad forehead. More important, he sensed her brilliance and passion for physics.

Ignoring the proper etiquette for a young lady, Marie Skłodowska gave Pierre Curie her address the very day they met. As a foreigner and student, she lived somewhat outside the bourgeois conventions of the day, and when they interfered with her life or work, she was prepared to overlook them. Later, she had dinner with Pierre and invited him to her room for tea. In return, he gave her Émile Zola's new book, just banned by the Catholic Church.

Pierre Curie was an idealistic dreamer. He had been raised in the republican, anticlerical tradition of the French Revolution. Unable to

adapt to school life, he had been tutored by his father and older brother. Pierre Curie, however, was certainly not part of the French scientific establishment. He had not attended the elite École Normale, and he taught at a new technical school for talented, working-class Parisians. There he earned approximately as much as a day laborer while conducting his famous magnetic experiments in a hallway between his lab and a staircase. Totally uninterested in awards for himself, Pierre Curie would see that his wife got her full share of credit for her scientific discoveries.

Maria Skłodowska still dreamed of returning to Poland to teach physics. Pierre Curie, on the other hand, talked about their sharing a life consecrated to scientific research. He argued, correctly, that she could do more and better research in France than in impoverished Poland. "It is necessary to make a dream of life, and to make a dream a reality," he wrote her. He asked her to marry him and, failing that, to share an apartment with him. Eventually, he made the ultimate sacrifice: he offered to give up his research career and live in Poland with her. At that, she gave in and agreed to marry him. Marie and his father, however, convinced Pierre to finish his doctoral dissertation in order to qualify for a professorship and a laboratory. His thesis on the relationship between temperature and magnetism became known as Curie's law. With his doctorate and a strong recommendation from the great English physicist Lord William Thomson Kelvin, Pierre Curie was promoted to professor and was paid the comfortable income of six thousand francs a year.

Marie and Pierre Curie were married in 1895 without rings, blessings, or priests. A relative gave them enough money to buy two bicycles, and wearing a split skirt and a black straw hat, Marie took off with Pierre on the first of many bicycle tours.

Marie Curie was studying for a teaching certificate in order to qualify as a professor in girls' high schools. In August 1896, she placed first in the teachers' examination and secured financial support from the metallurgical industry to study the magnetic properties of steel.

Managing a three-room apartment with little household help, she stripped her life of unnecessary details like curtains, rugs, and excess furniture. She cared little about houses but a lot about their gardens and the views from their windows. She also had a strong sense of her worth and superiority and did not like to waste her time on anything that bored her, like housekeeping.

Marie and Pierre paid none of the formal social calls that occupied so much time for others of their class. Instead, they visited relatives and held a Sunday afternoon open house for friends and students. Professors were government employees, so the Curie circle

was intensely interested in national politics. Their closest friends were a chemist, André Debierne; an eminent physicist, Jean Perrin, and his wife, Aline; and another physicist, Paul Langevin. Marie Curie focused her activities exclusively on science and her family—in that order—but she was knowledgeable and opinionated about political issues too. The Curies and their friends were leftist and anticlerical republicans who wanted the government to spend more for education and scientific research. While Catholic groups viewed science as morally bankrupt, the Curie circle thought in terms of moral and material progress, disease prevention, better agricultural methods, electric tramways, street lighting, and the like.

Two years after Marie and Pierre Curie were married and a month before Marie's thirtieth birthday, their daughter Irène was born. Pierre's widowed father moved in with them to care for the child while Marie worked. Even in liberal France, working mothers were almost unheard of, but both Curie men supported her desire to continue studying. She was one of only two women working for doctorates in Europe. A graduate student mother, she kept three sets of books: a baby's notebook, her lab reports, and her household accounts. She recorded Irène's first step as carefully as she recorded her scientific data and the cost of meat.

When Irène was three months old, her mother began looking for a research topic for a doctoral dissertation. The decision was not easy. At the beginning of the twentieth century, physicists believed that they had already discovered everything about the physical universe. As a prominent German physicist announced, "Nothing else has to be done in physics except make better measurements." Marie Curie's thesis, however, would blast physics wide open. More than anything else, her discoveries pointed to the powerful forces inside the atom, forces that physicists have spent the twentieth century exploring.

Few scientists paid great attention when Henri Becquerel discovered radioactivity in uranium in 1896. X rays, discovered the year before, had already grabbed the headlines and the glamour. Becquerel's radiation occurs when the heavy, unstable nucleus of an atom breaks apart and ejects its excess energy as clusters of protons and neutrons (called alpha particles), as superfast electrons, or as gamma rays of pure energy. Ironically, the more fashionable X rays are much less powerful; they originate in the clouds of electrons surrounding each atom. Marie Curie did not know the cause of radioactivity at the time, but she wanted to work in a totally new field where she could do laboratory research instead of library reading. Once she had decided on Becquerel's radiation for her thesis topic, Pierre Curie secured space at his college for her work.

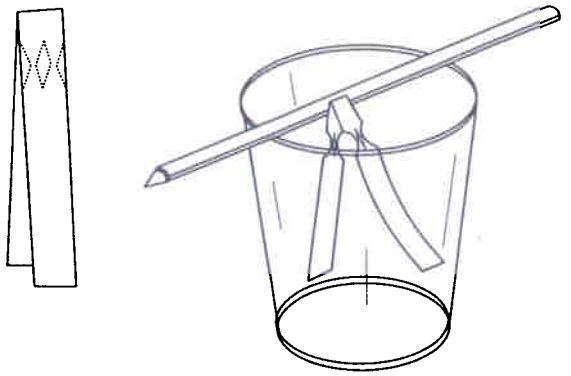


Fig. 2.1 An Electroscope.

For a simplified version of the instrument that Marie Curie used to detect radioactive substances, cut and fold a piece of gum foil. Tape it to a pencil in a glass to avoid drafts. Rub a metal pen or a balloon on wool to create static electricity and bring it close to one side of the foil. The strips separate and, as the electricity leaks away, close.

Becquerel had shown that the radiation emanating from the element uranium could blacken photographic plates, even those wrapped in heavy cardboard. He had also discovered that uranium makes the air around it conduct electricity. Marie Curie realized that this phenomenon, called ionization, could be used to detect radioactivity in other substances. So she decided to conduct a systematic search of all the known elements. She used Pierre Curie's invention, the piezoelectric quartz balance, to measure the weak electrical charges. Within days of starting her project, she discovered that another element, thorium, produces the same powerful effects as uranium.

Next, she decided to measure the strength of the electric current produced by different uranium and thorium compounds—that is, substances composed of uranium or thorium in combination with other elements. She discovered a simple, but totally unexpected, phenomenon: the strength of the radiation depends only on the amount of uranium or thorium in the compounds.

Normally, different compounds of the same element share few common chemical or physical properties, such as hardness, color, or solubility. For example, pure uranium is a heavy, shiny metal; one compound is a black powder; and another compound is a transparent, yellow crystal that glows green. Yet all three emit radiation

according to the amount of uranium they contain. Thus, she deduced, radioactivity does not depend on how atoms are arranged into molecules. Instead, radioactivity originates within the atoms themselves. This simple but breathtaking discovery is Marie Curie's most important scientific contribution.

Next, she had what the Nobel Prize-winning physicist Emilio Segrè considered a stroke of genius. She extended her research beyond uranium and thorium and their simple compounds to their natural ores. Testing museum samples, she discovered that two uranium ores—pitchblende and chalcolite—were three and four times more radioactive than could be predicted from the amount of uranium or thorium they contained. What could be producing the extra amount of radioactivity? She hypothesized the presence of an unknown, highly radioactive element in the ore. She also coined a new word, *radioactivity*.

In April 1898, Marie Curie wrote an article announcing her discovery that thorium was radioactive and her hypothesis that a new radioactive element existed within the ore. Unfortunately, only two months before, a German had also discovered thorium's radioactivity. However, he had not reached the all-important conclusion that radioactivity emanates from within the atom. Nor had he realized that the ores contained a new element.

Intrigued, Pierre Curie dropped his own beloved crystal research and joined Marie's radioactivity project. He never returned to crystals.

The Curies' only clue to the new element was its radioactivity. Breaking down pitchblende into its constituent chemicals, Marie and Pierre discovered that only two components—those mixed with either bismuth or barium—were strongly radioactive. Clearly, the barium and bismuth compounds must have something radioactive in them. So they began separating those compounds into their components as well. When the bismuth compound was heated red-hot in a vacuum, the radioactive element was deposited on the cooler part of the test tube. The new substance was four hundred times more active than uranium. Marie Curie named it polonium in honor of her native land. Not only had she discovered a new element, she had also opened a new field of physics; radioactivity became the primary technique for exploring the interior of the atom.

While separating out polonium at the end of 1898, Marie Curie also discovered a second, even more active element, which she named radium. A third radioactive element, actinium, was found in the pitchblende by André Debierne, the shy but devoted chemist who was reportedly deeply in love with Marie Curie.

The Curies announced the discovery of their two new elements, polonium and radium, in articles published in July and December 1898. For her work, Marie won a thirty-eight-hundred-franc prize from the French Academy of Sciences.

Logically, the next step was to isolate the elements. Based on their calculations, the Curies knew they would have to purify tons of ore in order to extract a few grains of radium salts. The only space large enough at the school was an abandoned dissection shed. The shack was stifling hot in summer and freezing cold in winter. It had no ventilation system for removing poisonous fumes, and its roof leaked. A chemist accustomed to Germany's modern laboratories called it "a cross between a stable and a potato cellar and, if I had not seen the work table with the chemical apparatus, I would have thought it a practical joke." This ramshackle shed became the symbol of the Marie Curie legend.

Marie and Pierre shared the physics and chemistry work, moving back and forth between the disciplines as they proceeded, according to their granddaughter Hélène Langevin-Joliot, a nuclear physicist who has studied their notebooks in detail. Marie Curie was the group's leader and its driving force, directing lab discussions and keeping the operation moving. Pierre added scientific concepts. Marie also did the heavy physical labor, well aware that she was doing menial work that any technician could have accomplished. "Sometimes I had to spend a whole day mixing a boiling mass with a heavy iron rod nearly as large as myself. I would be broken with fatigue at that day's end," she complained. Every winter, she was sick with pneumonia or some other serious illness, often for several months at a time. As she remarked later, "If we had had a fine laboratory, we should have made more discoveries and our health would have suffered less."

"And yet," she concluded, "it was in this miserable old shed that the best and happiest years of our life were spent, entirely consecrated to work." She had achieved her goal—a simple family life and some interesting work. As she confided to her relatives about Pierre, "He was as much and much more than all I had dreamed at the time of our union. My admiration of his unusual qualities grew continually."

Isolating radium salts from tons of pitchblende devastated their health. Besides handling radioactive material, they were breathing the radon gas emitted by radium. They spent hours in the shed, even eating meals that Marie cooked there. Almost a century later, their notebooks are still dangerously radioactive. Marie Curie later estimated that in a properly equipped laboratory the four years could have been compressed into one, minimizing their exposure to radiation. Marie was spared the worst, because she commuted twice

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weekly to Sèvres to lecture at a teachers' training college for women. She suffered a late miscarriage in 1903 after a long bicycling trip, but had a second healthy child, Ève Denise Curie, in 1904. Nevertheless, Pierre told a friend, Marie was "always tired without being exactly ill."

Pierre suffered more. While Marie liked to keep some radium salts glowing by her bedside, Pierre carried a test tube of it in his pocket to show friends. He performed medical experiments on his arm and showed that radium burns took months to heal. As he liked to point out, radium is one million times more radioactive than uranium. He and Marie loved to visit the shed at night to see the luminous test tubes, glowing like faint fairy lights.

Pierre, with Marie Curie's acquiescence, made the momentous decision not to apply for patents on the industrial processes they devised for extracting radium salts from ore. Like many scientists at the time, they believed that research should be "disinterested"—conducted for its own sake, not for any material rewards. The Curies were bitter because they did not have a proper laboratory, but they rejected an opportunity to make millions that could have been used for research. By September 1902, the Curies had isolated one-tenth of a gram of radium chloride from several tons of pitchblende. Marie also ascertained the atomic weight of radium at 226.

Radium was the most important element to be discovered since oxygen. Glowing with a bluish light, it emits electrically charged particles. A piece of radium roughly the size of a penny produces approximately five hundred calories of heat every day for a thousand years. Clearly, something important was happening inside the radium atoms. As late as 1897 when the electron was discovered, physicists had assumed that atoms were solid, indivisible, stable, and immutable. Yet radium was proof that some powerful force existed inside the atom, a force powerful enough to emit heat and give off light for years on end. In his lab, Ernest Rutherford showed that atoms of radioactive substances even change from one element to another. More than any other scientist, Marie Curie forced her colleagues to pay attention to the invisibly small world inside the atom. Scientists were forced to alter their definition of an element and to recognize a new force of nature.

The honors started pouring in at once. The British had always been Pierre Curie's greatest fans, and they asked him to speak to the eminent Royal Institution in London in June 1903. By then, he had violent joint pains and his legs sometimes trembled so badly that he could not get out of bed. The evening of his Royal Institution talk, his fingers were so covered with sores that he could barely dress himself. Observers thought he looked sick and feeble. As Pierre demonstrated the properties of radium and radioactivity, he fumbled, spilling some of Marie's precious radium; fifty years later, areas of the hall had to be decontaminated.

Marie was so busy working in her shed that she did not have time to present her doctoral thesis until June 1903. Her examining committee declared that her thesis, "Researches on Radioactive Substances," was the greatest scientific contribution ever made by a doctoral dissertation. That evening, the Curies celebrated with their friends, Paul Langevin, Jean Perrin and his wife, and Ernest Rutherford. One of the greatest experimental physicists of all time, Rutherford endeared himself to Marie when he confided that radioactivity is "a splendid subject to work on.... You know, it must be dreadful not to have a laboratory to play around in."

The June evening was warm, and at eleven P.M., the group moved outdoors into the garden. In the darkness, Pierre reached into his pocket and pulled out a tube of radium. Watching it glow, the group fell silent. Rutherford could see that Pierre's hands were so raw and inflamed that he could barely hold the tube. A doctor diagnosed rheumatism and prescribed strychnine.

In 1903, the French Academy of Sciences nominated Henri Becquerel and Pierre Curie to share the Nobel Prize for physics for their work on radioactivity. Marie Curie was not included. Luckily, one of the most powerful Swedish physicists on the nominating committee, Magnus Gösta Mittag-Leffler, was a great supporter of women scientists. The Swede wrote Pierre Curie that he and he alone was being considered for the prize.

Pierre was clearly Nobel Prize material for his magnetism research, but radioactivity was another matter. He cared little about prizes himself, but he wanted his wife to get credit for her work. So he wrote back to Mittag-Leffler, "If it is true that one is seriously thinking about me [for the prize], I very much wish to be considered together with Madame Curie with respect to our research on radioactive bodies." Pointing to her role in the discovery of radium and polonium, he added with Gallic logic: "Don't you think that it would be more artistically satisfying [*plus joli d'un point de vue artistique*] if we were to be associated in this manner?"

The problem was that Marie Curie had not been nominated for the 1903 prize. She had, however, received two nominations the previous year. With some bureaucratic sleight-of-hand, one of those nominations was declared valid for 1903, and she was nominated with her husband and Becquerel.

When the Royal Swedish Academy of Sciences met to discuss the Curies' nomination, it changed their prize in a small but crucial way. As originally conceived, the Curies would have won the physics prize

for "their discovery of the spontaneously radioactive elements." Chemists objected, however. They wanted to leave a way open to award the Curies a *second* Nobel Prize for the discovery of radium. "The discovery of such a singularly remarkable element as radium might eventually be considered for a Nobel Prize in chemistry," they argued. So the Academy decided to give the Curies the 1903 prize in physics for "their joint researches on the radiation phenomena discovered by Professor Henri Becquerel." Radium could wait for another year. Until the 1980s, when the Nobel archives opened its records of the 1903 debate, many scientists considered Marie Curie's second prize in 1911 undeserved because they assumed that it was awarded for her later, less crucial research.

The Curies were too sick to collect their prize in December 1903. It was eighteen months later before Pierre could give the obligatory lecture and pick up their prize money.

Marie Curie's Nobel Prize for Physics created two stars: Curie herself and the science Nobels. Until then, the press had paid no attention to the science prizes. The literature and peace awards received broad coverage, but the physics, chemistry, and medicine or physiology prizes were considered too esoteric for the mass media. Marie Curie made the science prizes so popular that the press never again ignored them.

Ironically, the public was enthralled with Marie Curie for her discovery of radium—the element that she had not yet won a prize for. Radioactivity was complicated, but radium was glamorous. It was expensive; it was a possible cure against cancer; and it was magical, changing one element into another and producing a seemingly inexhaustible supply of energy. Marie Curie symbolized both the selfless pursuit of science and its humanitarian benefits. She also personified the triumph of the lone individual against impossible odds. In France, her shed stood for governmental neglect of scientific research. The Curies' refusal to patent their discovery and their neglect by the French scientific establishment only fueled the legend.

By the end of 1903, Marie Curie was a household word, the world's most famous scientist. Her discovery of radium followed soon after the invention of the Linotype, telegraph, and telephone, which in turn created the mass media with their scandal sheets, popular magazines, and large-circulation newspapers. Reporters parked on the Curies' front step, hoping for exclusive interviews. Without receptionists, secretaries, or public relations officials to explain even the rudiments of radioactivity, the Curies were overwhelmed. "For a year now I have done no work, and I haven't had a moment to myself," Pierre Curie complained in July 1905. "Obviously, I haven't yet found a way to protect us from frittering away our time, and yet I must. It's a matter of life and death intellectually."

Both felt utterly fatigued. "We can no longer dream of the great work days of times gone by," Pierre wrote. "As to research, I am doing nothing at present.... My wife, on the contrary, leads a very active life, between her children, the School at Sèvres, and the laboratory. She does not lose a minute and occupies herself more regularly than I can with the direction of the laboratory in which she passes the greater part of the day."

She and Pierre still resented the inadequacy of their laboratory. The gateway to research facilities in France was a professorship in a major university. Between 1898 and 1904, the Curies had published thirty-six papers, won a Nobel Prize, and turned down an enticing offer for them both from the University of Geneva in Switzerland. Pierre, however, did not become a professor at a prestigious French university until 1904, when the Sorbonne, a part of the University of Paris, promised him a laboratory. At the same time, Marie became a professor at the women teachers' college at Sèvres and was told she would become superintendent of Pierre's laboratory when it was built at the Sorbonne. As late as 1906, however, the university had not begun construction. When Pierre was offered a prestigious award from the Legion of Honor, he refused it, saying "I do not in the least feel the need of a decoration, but I do feel the greatest need for a laboratory." He was never to have a "real" laboratory.

On Thursday, April 19, 1906, Pierre Curie attended a physics luncheon in Paris on his way to visit his publisher. Crossing a busy street in the rain while trying to open his umbrella, he tottered into a horsedrawn wagon. The driver frantically pulled on the reins, but a wheel rolled over Curie's head. His skull was crushed. Pierre Curie, the dreamer who had made Marie Curie's research possible, was dead at age forty-eight. They had been married eleven years.

Containing her anguish in public, Marie Curie calmly received visitors, told Irène that her father was dead, and helped lay Pierre's body out in the front room. In private, she filled a little gray notebook with heartfelt grief. In a series of love letters to Pierre, she moaned, "What a terrible shock your poor head has felt, your poor head that I have so often caressed in my two hands.... We put you into the coffin Saturday morning, and I held your head up for this move. We kissed your cold face for the last time. Then a few periwinkles from the garden on the coffin and the little picture of me that you called 'the good little student' and that you loved. It is the picture that must go with you into the grave."

Marie Curie appeared close to a breakdown but, within two

weeks, she was writing business letters about the laboratory. When friends suggested taking up a collection and securing a widow's pension to help her, she vehemently refused. She insisted on being considered a scientist, not a helpless widow. After some hesitation, the University of Paris offered her a position as an assistant lecturer at ten thousand francs yearly, starting May 1, 1906. It was her first university salary, and she would be the first woman professor in the Sorbonne's six-hundred-and-fifty-year history.

On November 5, 1906, the fifteenth anniversary of her enrollment as a student at the Sorbonne, Marie Curie entered its physics auditorium to give her first lecture. As usual, when speaking in public, she was nervous. The auditorium looked more like a theater than a classroom. Society women in formal dresses and large elaborate hats filled the front rows. A stenographer sat ready to save every word for posterity. Newspaper editors—no mere reporters—took notes. What they understood of her lecture is unclear. As one wrote, "The magnificent forehead won notice first. It was not merely a woman who stood before us, but a brain—a living thought."

After five minutes of fervent applause, Marie Curie quietly began where her husband had left off, "When we consider the progress made in physics in the past ten years, one is surprised by the..." If the audience had hoped for histrionics and melodrama, she did not intend to oblige. Instead, she built a shield of impassivity around her to mask her feelings. She rarely spoke about Pierre Curie to anyone; even late in life, she found it difficult to talk about him with her daughters. She reserved her private thoughts for the little gray exercise book. There she wrote, "My little Pierre, I want to tell you that the laburnum is in flower, the wisteria, the hawthorn and the iris are beginning. You would have loved it all. I would also like to tell you that they've given me your chair, and some imbeciles even congratulated me on it." In the fall of 1908, while editing Pierre Curie's papers, she became a full professor of general physics.

A few months after Pierre's death, Marie Curie faced a scientific crisis. In August 1906, Lord William Thomson Kelvin wrote the editor of the *Times* of London to announce, incorrectly, that radium was not an element after all. It is, he said, merely a compound of lead and helium. Kelvin's letter precipitated a controversy and threatened Marie Curie's position in science. Lord Kelvin, one of the most important scientists of the day, had been Pierre Curie's biggest supporter; it was Kelvin who had urged the Municipal School to make him a professor. For Kelvin to cast doubt on the element radium was devastating.

Marie Curie, however, could not prove him wrong. Although she had isolated radium chloride in 1902, she had not produced pure

radium. To defend her discovery, she began another arduous four-year project to purify the radium salts. In the end, with enormous persistence and determination, she produced a few grains of pure radium. She had proved that radium is indeed an element.

While struggling to purify radium, she was also building a new life as a single parent. Pierre's father remained with her to care fondly for Irène and Ève until his death in 1910. To spare herself memories of Pierre, she moved the family first to a Parisian suburb and finally to a large apartment in central Paris. Because she disliked the rigid French school system, she organized a cooperative school for little Irène and her friends; she and other Sorbonne parents taught the classes.

Concerned that the children might be exposed to tuberculosis, she insisted on outdoor exercise for the girls. She took them backpacking and saw that they learned gymnastics, swimming, boating, horseback riding, and skiing, as well as sewing and cooking. During the 1920s, she built a summer house for August vacations in the Breton fishing village of L'Arcouest where many Sorbonne professors summered. And since she enjoyed swimming in warm water, she built a house for herself on the Riviera.

Despite Marie Curie's formidable determination as a scientist, she often appeared timid and vulnerable to her daughters. By the time Ève was a young girl, her mother had pared their social lives to the minimum. When she had to face a large group, she suffered physically. On days when she taught classes, she seemed like a different person.

She still did not understand the ramifications of being a twentieth-century media celebrity, however. Four years after Pierre Curie's death, she made two disastrous mistakes that engulfed her in publicity and scandal in 1911.

First, she assumed that she could seek election to the prestigious French Academy of Sciences like any other ordinary professor. She had forgotten that she was world famous in part because she was the Sorbonne's first *woman* professor. As a member of the Academy, she would be able to present research at the Academy's weekly meetings and publish it free of charge a few days later in the Academy's journal, the most prestigious scientific publication in France. To help her research group, she decided to announce her candidacy for the Academy. A sixty-six-year-old devout Catholic man, close to retirement, was already in the race.

With Curie in the running, the character of the contest abruptly changed. It was no longer a sedate competition between eminent academics. Instead, it became a sensational press campaign between, on the one hand, liberals, feminists, and anticlerical groups and, on

the other hand, nationalistic Catholics and anti-Semites opposed to the election of a foreign woman. On January 23, 1911, Curie lost by one vote. She received the news by telephone in her laboratory. Hiding her dismay, she returned to work without saying a word. Her assistants, who had hidden a congratulatory bouquet under a workbench, said nothing either. She never again sought membership in the Academy, and for the next ten years she refused to publish in its journal. As for the Academy, it refused to admit women until 1979—sixty-eight years later.

Curie's second mistake was catastrophic. Once again, she underestimated the hatred that a woman in her position could generate. She assumed that a forty-three-year-old widowed professor could have a private relationship with a married man.

Paul Langevin was a gifted and influential French physicist who had been a student and friend of Pierre Curie. Langevin and Marie Curie were two of the first French scientists to recognize the importance of quantum theory and Einstein's relativity theories. Most French scientists regarded the theories as Germanic and anti-French.

In 1911, Langevin was a handsome and charming ladies' man, five years younger than Marie Curie. With beautiful chestnut brown eyes and a flowing mustache, Langevin enjoyed being taken for an army officer. His marriage had been a battlefield for years. His wife and in-laws wanted him to quit research and take a highly paid job in industry. Curie and her friends wanted to "save him for research."

When Langevin rented two rooms on the Rue du Banquier, a ten-minute walk from Curie's laboratory, she began visiting him daily. Buying food in nearby shops, she prepared their lunch in the flat. Neighbors later told the newspapers that they "behaved like lovers."

At some point that year, Paul Langevin's desk was broken into and a drawer was forced. Mme. Langevin and her brother-in-law came into possession of some letters. Curiously, all of them were undated. Even stranger, some were letters from Marie Curie while others were from Langevin himself to Marie Curie. Why his letters were in his own desk instead of in hers has never been explained. But then again, the letters may not have been genuine. No one will ever know because, following the death of Langevin's wife, her son burned them. According to Curie's friends, the letters were clever pastiches assembled from genuine letters in order to incriminate the pair.

Rumors circulated all summer. On October 26, Jeanne Langevin began proceedings to secure a legal separation. A few days later, while Curie and Langevin were attending a physics conference in Brussels, *Le Journal* broke the story: "A Story of Love. Mme. Curie and Professor Langevin." In late November, a rabidly xenophobic, anti-Semitic tabloid published excerpts from letters filed in court during the legal proceedings.

Today these letters—urging Langevin to leave his wife before he got her pregnant again—barely qualify as love letters. They seem more indiscreet than scandalous. A modern audience might even be delighted that two unhappy people had found romance and companionship. Had Marie Curie been a male professor, turn-of-the-century French readers might have agreed. In 1900, affairs were commonplace in France, abortionists ran classified advertisements in the newspapers, and one-quarter of all French births were illegitimate. The Sorbonne had overlooked affairs conducted by its male faculty members.

But to the right-wing press, Marie was a Pole who had stolen a Frenchwoman's husband. Curie and science were regarded as immoral, anti-French, and probably Jewish. The affair shook the University of Paris and the French government at the highest levels. Had it not been for a handful of close friends, Marie Curie would have left France and returned to Poland. It was not until Jeanne and Paul Langevin reached an out-of-court settlement on December 9, 1911—with no mention of Marie Curie—that the scandal subsided.

At the height of the sensationalism, on November 4, 1911, Marie Curie received a letter from the Nobel Foundation notifying her that she would be awarded a second Nobel Prize, this time in chemistry for her discovery of radium. It was the prize that the Nobel Committee had paved the way for in 1903 by excluding radium from her first Nobel. With Pierre dead, she shared this award with no one.

The timing of the second award may not have been coincidental, however. It had been engineered by Svante Arrhenius, an eminent Swedish physicist and a powerful figure on the Nobel committees. Arrhenius may have heard rumors about the impending scandal and arranged a show of support. Curie had received only two nominations in 1911, one of them from Arrhenius himself.

Leaving Paris behind, Marie and Irène Curie traveled to Stockholm. In her speech, Marie Curie clarified precisely what she had contributed to the discovery and what Pierre had accomplished. "The study of this phenomenon was extended to other substances, first by me, and then by Pierre Curie and myself.... I have turned.... I was struck by..." and so on.

On her return to Paris, Marie Curie collapsed and was taken on a stretcher to a nursing home, where she was admitted under an assumed name. Convinced that she had besmirched the Curie name, she insisted on using a pseudonym even to correspond with Irène. It was a year before she resumed work.

Given the social climate of the day, Curie and Langevin had to

end whatever romantic relationship had existed. Two years later, Langevin returned to his wife. Surprisingly, Marie Curie's granddaughter and Paul Langevin's grandson later married without any inkling of their grandparents' famous scandal. Jeanne Langevin attended the wedding and held her tongue. Today Hélène Langevin-Joliot is "more than eighty percent sure an affair occurred, but things were so different then, and people were so different. Conceivably, Langevin's apartment might have been for his work, to get out of the house, and to have an office." Although many assume that there was an affair, no one will ever know for sure—precisely what Marie Curie would have wanted.

As for Marie Curie, she retreated once more into her shell, hiding her emotions. She had learned that, for the Vestal Virgin of Radium, romance was simply too dangerous. It was the summer of 1913 before she had recovered enough to supervise the construction of her physics institute and go hiking with her daughters, her old friend Albert Einstein, and his young son.

By the time World War I broke out in August 1914, Marie Curie was ready for action again. Unlike the French medical corps, she realized immediately that X rays would be invaluable for treating shrapnel and fracture wounds in front-line hospitals. Hiding her priceless radium supply in a Bordeaux bank vault, she returned to Paris and began organizing a mobile X-ray service. Ten days after the war started, she filed a formal request with the Minister of War for approval to begin work. All through August and September, she visited Parisian laboratories and wealthy women to ask for equipment, cars, and money. Her first vehicle—called a "petite curie"—was ready for the Battle of the Marne in November 1914. By the end of the war, she had opened two hundred X-ray stations in French and Belgian battle zones and trained one hundred and fifty women technicians, including her daughter Irène. Altogether, her X-ray units examined more than one million soldiers.

In addition to running the X-ray service, Curie began collecting the radon gas that emanated from her radium. Enclosing the gas in tiny glass tubes, she shipped it to hospitals around the world for use against cancerous tumors. For forty-eight hours after every radon session, she felt utterly exhausted. By now, she had been exposed to more radiation than any other human being.

The French government never recognized Marie Curie for her war work. Not even her patriotism could wipe out the memory of the 1911 scandals. Nevertheless, she had learned valuable lessons. She now knew that she could raise money, negotiate with government officials, and administer a large operation. Above all, she realized

that it was possible to use the Curie name and fame to promote a cause.

Marie Curie dedicated the rest of her life to building a French research institute for the study of radioactivity. Germany, Great Britain, and Denmark had already established physics institutes where groups of scientists could work together on common problems. The group approach had proven extremely successful. Although French biologists could study at the Pasteur Institute in Paris, French physics professors still worked alone or with two or three students at most. Before World War I Curie had begun talking with representatives of the University of Paris and the Pasteur Institute about a research center where scientists could do basic research in radioactivity and where physicians could apply that research to medical problems. A building for the institute was completed just before the war broke out.

When the Radium Institute opened after World War I, Marie Curie was more than fifty years old, physically ill, and emotionally exhausted. Her institute had a building but little more, not even a typewriter. With the French economy devastated by postwar inflation, she was unlikely to get financial support from government officials, industrialists, or philanthropists. None of them had supported scientific research even when times were good.

The Curie circle tried to convince the French public that a nation that does not invest in research is a nation on the decline. Unfortunately, France preferred the image of poor self-sacrificing scientists like Louis Pasteur and Marie Curie toiling in their attics and sheds. Supporting her colleagues' efforts to build French science, Curie helped lobby government officials. Recognizing that scientific discoveries could be used to finance research, she even changed her mind about scientists' patenting their discoveries. These were all long-term campaigns, however, and the institute needed money immediately.

In 1920, a friend asked her to see a leading American journalist named Missy Meloney. Meloney was tiny and frail; she limped from a childhood accident and suffered from tuberculosis. The first woman with a seat in the press gallery of the United States Senate, she was editor of the *Delineator*, one of the largest women's magazines in the United States at that time. As she described herself, she was "busy as a switch engine....Life for me has become like a highly charged electric wire, and I cannot let go." Her cable address was IDEALISM.

At the institute, Meloney waited to meet Curie in a bare little office filled with cheap furniture. "The door opened and I saw a pale, timid little woman in a black cotton dress, with the saddest face I had ever looked upon. Her well-formed hands were rough. I noticed

a characteristic, nervous little habit of rubbing the tips of her fingers over the pad of her thumb in quick succession. I learned later that working with radium had made them numb." Face to face with the saintly Curie, the fast-talking Meloney was speechless. To make conversation, Curie explained that U.S. researchers had approximately fifty grams of radium. "And in France?" Meloney asked.

"My laboratory has hardly more than a gram."

According to Meloney's story, she promptly declared, "You ought to have everything in the world you need to go on with your work. Someone must undertake this."

"Who will?" Curie asked rather hopelessly.

With a flourish, Meloney promised, "The women of America." Curie did not think Meloney would do anything, but she did think the American was sincere.

Meloney pulled it off. She arranged one of the largest fundraising campaigns the world had ever seen. First she secured promises from New York City's newspaper editors not to print a word about the Langevin scandal. Incredibly, the editor of the sensationalist Hearst newspapers even gave her its Langevin file. Then she appointed fundraising committees of wealthy women and physicians and raised one hundred thousand dollars to buy Curie a gram of radium. She arranged a gala tour of the United States, honorary degrees from twenty universities, and a White House reception with President Warren Harding.

The event was so spectacular that even the French contributed money, though most of it came from Jewish philanthropists. Meloney knew few American women scientists, however, so the campaign benefited Marie Curie without helping other women in science. In fact, by creating an almost impossible standard for women scientists to live up to, Marie Curie may have made their professional progress more difficult. Although universities did not expect every male scientist to be an Albert Einstein, women scientists were continually measured against Marie Curie—and naturally found wanting.

When Marie, Irène, and Ève Curie arrived at the dock in New York City, they were greeted by cheering crowds, bands, banners, confetti, and frenzied newspaper reporters. Ève and Irène had had no idea their mother was so famous. They were stunned by the assault of journalists shouting at her, "Turn your head left," "Turn your head right." Irène and Ève knew their mother as a quiet professor. This celebrity was no one they knew.

Marie Curie proved to be a public-relations dream. Her black-garbed, self-effacing appearance was the embodiment of the selfless scientist. As the *Scientific American* gushed, she was "unassuming, plainly but neatly dressed, womanly and motherly in appearance.... She remains just plain Madame Curie, working for the good of humanity and for the expansion of scientific knowledge."

The three-week trip exhausted Curie, but she returned in 1929 for a second Meloney extravaganza and collected enough money for a gram of radium for Poland. Meloney had become Curie's close friend and confidante. Their second tour ended just three days before the stock market crash of 1929.

The glamour of the Curie name financed an international research center in France. Although she continued to do research, helping to untangle the process by which radioactive elements decay into other elements, she spent the rest of her life organizing, administering, and fundraising for the institute. Thanks to her, the Radium Institute became one of the world's leading centers for nuclear research. In it, Marguerite Perey discovered francium, a new radioactive element; Salomon Rosenblum analyzed alpha rays; and Irène Curie and her husband, Frédéric Joliot-Curie, discovered artificial radioactivity. Curie reserved a certain number of positions for foreigners and women each year. In 1933, out of approximately forty scientists at the institute, seventeen were foreigners.

In addition to the institute, Curie became a major force behind the internationalization of physics. She helped Poland develop a radium institute, worked with a League of Nations committee on international publishing standards and student fellowships, helped establish the international standard for radium units, and donated radium and radon to researchers around the world.

Between her two American tours, Curie underwent four cataract operations. (Cataracts are among the first symptoms of radiation sickness.) At one point, she was so blind that her lecture notes were printed two-and-a-half inches high and Irène had to guide her to and from work. Marie tried to hide her condition, visiting her ophthalmologist as Madame Carr.

By the mid-1920s, evidence was accumulating about the dangers of radium. In 1924, a New York dentist discovered that the young women who painted radium on watch faces were dying of cancer caused by licking their paintbrushes into points. Several of Curie's lab workers died of anemia and leukemia during the 1920s, and she herself had a raft of symptoms, including anemia, tinnitus in her ears, and chronic exhaustion. The institute, however, did not conduct research on the health problems associated with radium. Institute rules were to economize on water, gas, and electricity; not to smoke in the labs; and to change lab coats and breathe fresh air deeply whenever outside. Part of the problem was that Marie Curie herself

was so strong. Fresh air, ocean swimming, and mountain climbing improved her health. When the employees died, Curie blamed them for not taking enough fresh air.

Although she ignored health hazards, she remained absolutely up to date on new developments in physics. The year before she died, she attended a conference and was often heard correcting her scientist daughter and son-in-law on facts.

Toward the end of her life, she made one last effort to insure her privacy. Sorting through her files, she destroyed almost all her personal papers, leaving only her love letters from Pierre, letters from a beau she had known during her student days, and the diary she had written after Pierre's death. They were testaments to her desirability and to the strength of the love that she and Pierre had shared. She saved nothing from the Langevin years.

She also organized an orderly transition at the institute, arranging for her aide Debierne and then Irène to take over. The year before her death, she witnessed the discovery of artificial radioactivity by Irène and her husband, Frédéric Joliot. Their work would make the institute's stockpile of natural radioactive elements obsolete, but it ensured a Nobel Prize for Irène.

At sixty-seven, Marie Curie was still consumed with curiosity and a spirit of scientific adventure. As she wrote, "I am one of those who think that science has great beauty. A scholar in his laboratory is not just a technician; he is also a child face to face with natural phenomena that impress him like a fairy tale." A few weeks before her death, she hiked alone partway up Mont Blanc to watch the sun set over the mountains.

On July 4, 1934, she died of leukemia in a nursing home in the French Alps. Death came slowly, her powerful heart continuing to beat long after all hope had gone. During her last two days, she said nothing about her family. Instead, her mind passed among little shreds of an experiment. For Marie Skłodowska Curie, all but science had disappeared.

* * *

3

Lise Meitner

November 7, 1878–October 27, 1968

NUCLEAR PHYSICIST

USING A PRIVATE ENTRANCE, Lise Meitner entered her basement laboratory—and stayed there. A former carpentry shop, it was the only room in Berlin's chemistry institute that she was permitted to enter. No females—except, of course, cleaning women—were allowed upstairs with the men. Prohibited even from using a rest room in the chemistry building, she had to use facilities in a hotel up the street.

For two years, from 1907 to 1909, Meitner performed radiation experiments in the cellar, careful never to be seen upstairs. Normally shy and timid, she sometimes longed so desperately to hear a chemistry lecture that she sneaked into the amphitheater upstairs and hid under the tiers of seats to listen.

Ten years later, Lise Meitner was the director of a center for radiation physics in Berlin. For twenty years, she reigned supreme there, creating one of the glories of the golden age of physics in the 1920s and 1930s. Later, fleeing Nazi persecution, she left Germany illegally and went into exile. At the age of sixty, she deciphered the experiment of the century by explaining that, incredibly, the nucleus of an atom could split and release enormous amounts of energy. For the fission experiment that she initiated and explained, her German partner received the Nobel prize.

Lise—pronounced *lee-zel* without the "t"—was born in 1878, the third of eight children in a gifted and liberal Viennese family. Her grandparents were Jewish, but her lawyer father, Philipp Meitner, was an agnostic. He encouraged his eight children to learn about science, and two of his daughters and a son earned university degrees. Lise's mother, Hedwig Skovran Meitner, was a talented pianist who taught her children music. Lise's oldest sister became a concert pianist and composer. Music and physics became Lise's two grand passions.

As a child, Lise noticed a beautiful, iridescent puddle of water