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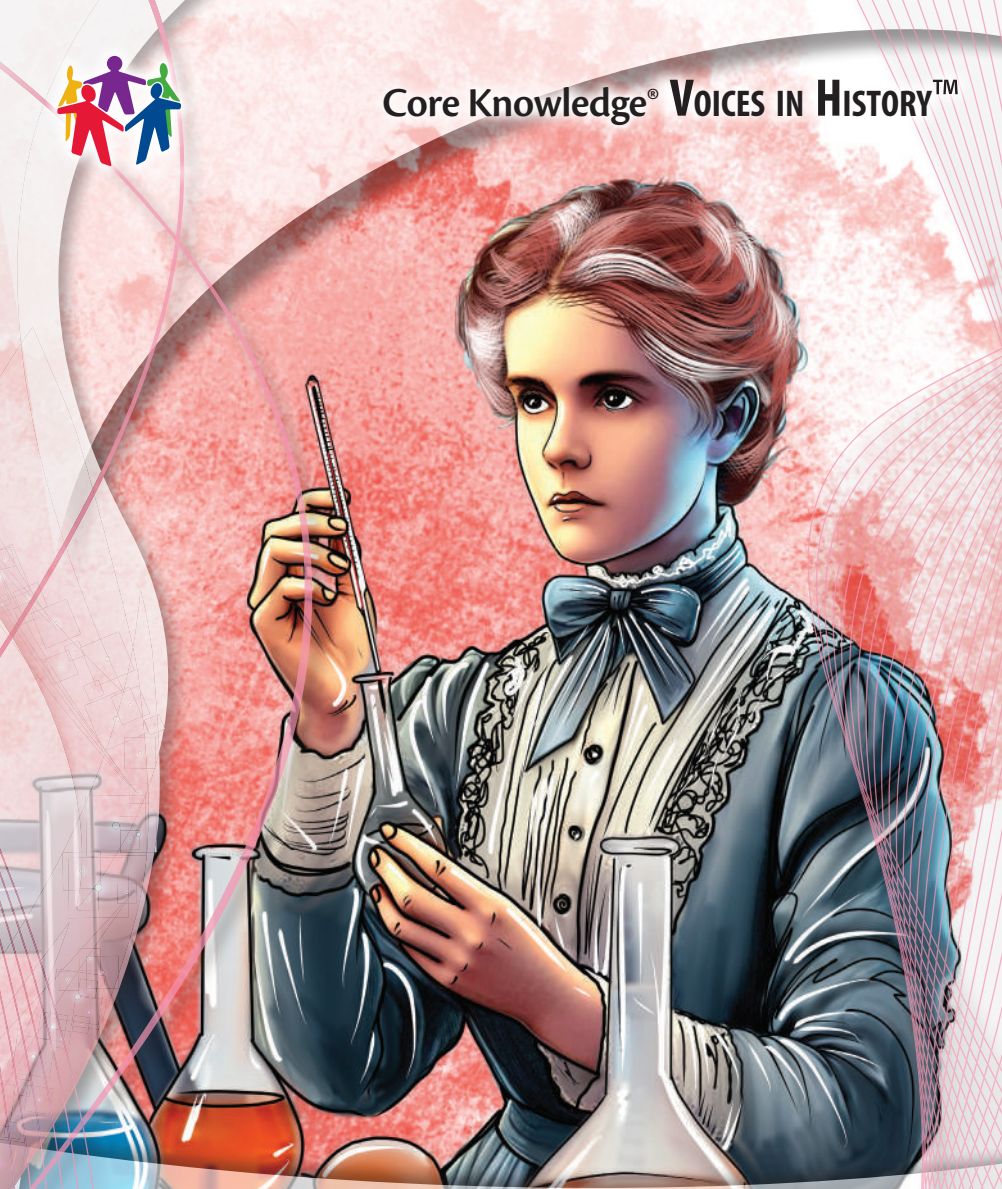

# Marie Curie

## The Invention of Knowledge

by Beth Kephart

illustrated by Kailien Singson

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# Marie Curie

## The Invention of Knowledge

by

*Beth Kephart*

illustrated by *Kailien Singson*

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# 1

## Gifted

In a certain cramped apartment in the heart of Warsaw, Poland, in the year 1873, you couldn't get away from the noise.

A book slamming shut. A muffled argument. A boy counting out loud or whistling a tune or exactingly enunciating the laws of mathematics or boasting about some new thread of knowledge. Creaking chairs stuffed into corners. Wobbling tables wedged where they fit. Bodies hot or cold or twitchy. Pencils rolling and piles of papers thudding to the floor. A voice calling out from a dream. Boys. Everywhere: boys.

*Give me that.*

*That's mine.*

*I said stop it.*

Or something like that.

It's so easy to imagine.

Born on November 7, 1867, Marya Salomea Skłodowska, now five years old and the youngest of five children, might have wished for a private, quiet

place to dream in this apartment that her only brother, Józef, would later call a "beehive." Her mother was away at a sanatorium, seeking treatment for her infectious tuberculosis. Her father, a widely read math and physics teacher, had recently lost his job as the assistant director of a boys' gymnasium (a type of secondary school). With the family's income suddenly reduced and the cost of Marya's mother's care rising, Marya's father had converted their apartment into a stinky, noisy, distracting boys' boarding school. Crowded with boarders at night, the place was even worse by day, thanks to the increasing number of day students that Marya's father took into his ad hoc school.

**sanatorium:** a medical facility for treatment of long-term illnesses, often through fresh air, rest, mild exercise, and a healthy diet

**tuberculosis:** a bacterial infection of the lungs that causes fever and difficulty breathing

The boarding boys slept in the family bedrooms. Marya and her sisters slept in the living room, among the books and tools of the students and their tutors. Those dirty shoes. Those broken pencils. Their father's attention divided. Making it all so much worse was the absence of Marya's mother, whom all the children dearly loved. She'd been so sick throughout Marya's childhood that she hadn't even been able to kiss her youngest or hold her tight for fear of passing on the disease that was slowly killing her. And now she was gone—so far away, replaced by loud and needy boys.

***Russian Occupation of Warsaw***

*In the mid-1500s, Poland was one of the largest and most powerful countries in Europe. That changed when Austria, Prussia, and Russia began to divide and conquer this near neighbor.*

*During the early and mid-nineteenth century, many Polish people fought to regain their culture and language, but their uprisings proved futile, and many of the dissenters were either killed or sent to Siberia. By the time Marya Skłodowska was a child, the Russians had overtaken her city.*

*Marya's father angered Russian bureaucrats due to the public pride he took in his Polish heritage. The very principles the family sought to live by placed them under suffocating suspicion. The Russification of Warsaw had an additional, profound impact on young Marya. For one thing, only Russian language, history, and culture were to be taught in the schools. For another, girls and women were denied the educational opportunities given to boys and men.*

**bureaucrats:** government or administrative officials

Operating a boarding school inside one's own cramped quarters was hardly ideal. But it was the only way Marya's father knew to get by. He'd lost his job, and he'd lost his money in a bad business investment (a brother-in-law's mill). His wife, a brilliant and beloved former headmistress of a private girls' academy, was unwell and far away.

Cash was tight. There was a family to house and feed, a wife's medical expenses to pay. A boarding school paid some bills, if not enough. But taking in students may well have led to the tragedy that happened next. In January 1874, typhus, a disease that spreads in crowded conditions, struck two of Marya's older sisters, Zofia and Bronya. Zofia, the oldest, would not survive; she died two years later at age fourteen. Then, in May 1878, when Marya was ten, her mother finally succumbed to tuberculosis.

Losses like these leave deep and not entirely knowable impacts. Marya, who would someday be known as Madame Marie Curie, would carry a sadness with her for the rest of her life. She would also be driven to succeed.

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**typhus:** one of several infectious diseases caused by bacteria, often leading to fever, headache, and a rash

**succumbed:** gave in to, was overwhelmed by, or died as a result of something

Marie Curie's life's work in physics and chemistry and on the matter of radiation would yield hugely complicated outcomes. It would change millions of lives for the better (through, for example, cancer treatments). It would also change lives for the worse (while Marie Curie never worked on the atomic bomb, her breakthrough understanding of radiation was integral to its making). Marie's life would be marked by poverty and fame, scandal and heroics. She would argue for her place in laboratories and in the world while remaining humble and clear-eyed about her failures.

"Life is not easy for any of us," Marie Curie would write later in a letter to her brother while attending the University of Paris. "But what of that? We must have perseverance and above all confidence in ourselves. We must believe that we are gifted for something, and that this thing, at whatever cost, must be attained."

**radiation:** energy emitted in the form of waves or particles
**atomic bomb:** an explosive device whose power results from the splitting of atomic nuclei
**perseverance:** continued effort despite difficulties, failures, or obstacles

# 2

## Curiosities

If there had only been sadness in Marya's life, she would never have experienced the great joy of knowing. But that joy was there, too, from the beginning.

There were, for example, the games her sister Helena remembered playing. Geography games that sent the children off toward fantasies of travels. Collage art, which had them sifting through history books and magazines for the treasured images they would assemble. Stories told by their father, who would read to them in the many languages the children spoke—or translate works in languages they didn't speak, such as Charles Dickens's *David Copperfield*, into Polish.

*Tell us another story.*

*Read it again.*

*Please?*

*Please?*

And then there were those curiosities kept in their father's office—the physics equipment he had once relied on as a secondary school teacher. Minerals gleaming in their glass cabinets. Mysterious transparent tubes. A barometer with golden needles. A gold leaf electroscope, which somehow measured electricity (how did *that* work?).

Marya grew up fluent in both Russian and Polish. She was an early reader who had taught herself to read by the age of four, and her prodigious memory made itself known in ways large and small (*Memorize this poem, Marya. Show us what you can do*). Puzzling through mysteries, asking so many questions, Marya was impatient, sometimes moody, always interested and interesting.

But getting a good education as a girl in Russian-occupied Warsaw was hardly a straightforward endeavor. At first, Marya attended the school where her mother once worked. Then in 1877, as a third grader, she was enrolled in a radically progressive private school that was closer to home. Its leader, a heroic schoolmistress named Jadwiga Sikorska, oversaw a secret curriculum of

**barometer:** an instrument that measures atmospheric pressure
**electroscope:** an instrument that detects and sometimes measures electric charge
**prodigious:** very large or extraordinary

Polish subjects taught in the Polish language—when the Russians weren't eavesdropping.

But whenever the authorities checked in, everything changed. Suddenly the teachers were teaching in Russian, and the students were reciting in Russian. If a Russian official raised his eyebrow or asked questions, if the secret teaching was about to be exposed, the teacher would often call on Marya—the girl with the best memory—to recite long, tedious passages from Russian poems. This was not a job that Marya liked. She wanted to hide, to disappear. *Call on someone else*. And yet Marya knew that her skills could save the school and allow the secret Polish teaching to go on.

One year later, just months after her mother's death, Marya's father placed her in Gymnasium Number Three, a government-run school where Russian was strictly enforced and even whispering to a friend in Polish was a punishable offense. The school days were long and tedious.

Marya graduated from that gymnasium in June 1883, at the age of fifteen. It was a surprise to none that she was first in her class and the recipient of a gold medal, but what was she supposed to do now? Had she been a man, she might have followed her brother to Warsaw University. But women were not allowed in those academic halls.

Some traveled to Paris or other places where young women joined young men in the classrooms, but Marya couldn't afford that. And so, exhausted and, in the eyes of those who loved her, depressed, Marya took a year off from studying to spend time with family in the country. There, in the fresh air, in the fresh streams, she swam. There, among cousins and friends, she ate. She rowed. She danced. She did not think of science. She was a carefree girl for what would be the only time in her whole life.

Small flirtations.

Silly games.

Laughter late into the night.

It would all have to last her a lifetime.

A year later, Marya returned home. To make some very necessary money, Marya offered private tutoring in subjects like French and math. But her desire for a good education once again burned bright. And so Marya joined an underground society called the Flying University, in which young women met in secret, in groups of ten or less, to learn.

Picture it: Young women in private apartments, huddled together, whispering, sharing books and pencils and discoveries. Young women in dark buildings after

hours, being introduced to subjects like anatomy and natural history under the tutelage of Polish scientists, historians, and philosophers. Young women learning from anyone who dared to teach whatever they knew how to teach in the rooms of whoever dared to host them. With the Russian police on the prowl for such subversive gatherings, the students and their volunteer teachers were forced to endlessly cover their tracks. From apartment to apartment they went, flying beneath the radar, alerting one another, quietly:

*Look at this.*

*Listen.*

*Did you know?*

***Marya's Memories***

*"I have a bright remembrance of the sympathetic intellectual and social companionship which I enjoyed at that time. Truly the means of action were poor and the results obtained could not be considerable; yet I still believe that the ideas which inspired us then are the only way to real social progress. You cannot hope to build a better world without improving the individuals. To that end each of us must work for his own improvement, and at the same time share a general responsibility for all humanity, our particular duty being to aid those to whom we think we can be most useful."*

**anatomy:** the study of the structure of living beings
**tutelage:** instruction
**subersive:** intended to overturn an established order

There was always more—more to learn, more to find out, more to share with other young women like herself. Often, Marya could be found at a local dressmaking shop, reading to the seamstresses while they worked. She could be found reading and drawing and writing poems, scribbling her questions into notebooks. Her mind never stopped. She could not stop it.

Soon, Marya and her sister Bronya were dreaming of studies abroad, where Polish women did not have to hide their curiosity and talents. Marya, it was decided, would work to earn the money Bronya would need to study medicine at the Sorbonne in Paris. Once Bronya completed her studies and began earning a wage of her own, she would in turn support Marya in her own studies. Barely eighteen years old, Marya left her father's house "to begin an independent life" by working as a governess—first for a family in Warsaw that she simply could not stand and then for another in a village miles away.

This departure from home was particularly painful. Marya was leaving her childhood behind. She was stepping into a life of hard work dictated by the demands and expectations of a family that was not her own. And she was leaving her father, for whom she had special love and who seemed to be aging quickly.

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**seamstresses:** women who sew for a living
**governess:** a woman who cares for and teaches a child in the child's home

***Marya's Memories***

*"That going away remains one of the most vivid memories of my youth. My heart was heavy as I climbed into the railway car. It was to carry me for several hours, away from those I loved. And after the railway journey I must drive for five hours longer. What experience was awaiting me? So I questioned as I sat close to the car window looking out across the wide plains."*

As a governess in the country village, Marya spent long hours tending to the education and care of her employer's children. At the same time, her employer, the owner of a beet-sugar factory, allowed Marya to teach local children how to read and write in Polish in her spare hours—a dangerous undertaking, given the Russians' prohibition of such activities. In whatever spare time she had left, Marya taught herself about the world through whatever books she could find—books on physics, sociology, and anatomy, among other disciplines—in a variety of languages. When she needed a break from reading, she practiced solving algebra and trigonometry problems.

It was nonstop, Marya's need to know. It was early in the morning and late at night. It was sleep sacrificed for the sake of a scientific formula or a mathematical curiosity. It was the sound of turning pages and a scratching pencil, the sound of Marya re-fluffing her pillow to continue reading, imagining and remembering and wanting.

**sociology:** the study of society and social interactions

Still, there were so many gaps in her education. So much that she did not know.

It was in this place of many children and long studies that Marya met the family's eldest son. He'd arrived home from college for the holidays, handsome, charming, intriguing, and bright. His name was Kazimierz Żorawski. He saw Marya for who she was: the depth of her intelligence, her curiosity and spark. Soon the two were madly in love, but when they announced their engagement, Kazimierz's parents—Marya's employers—said, quite simply, no. Marya had no money, after all. She had no apparent prospects. She may have been good enough to teach their children, but she wasn't, his parents said, good enough for Kazimierz.

The injustice was impossible. At first, the two refused to break apart. The relationship continued in secret for a time, until finally Kazimierz called it off for good, crushing Marya's heart.

He had been the one.

Now he was gone.

Marya couldn't imagine falling in love again. She craved an intelligent, educated partner, someone who would share her deep need to understand the ways of the

world and its many mysterious equations. Partners like that were rare. Chances were she'd lost the only one she'd ever find.

Still, as governess to the family, Marya stayed. Marya and Bronya had, after all, forged a plan. Marya had agreed to make the money her sister needed to complete her medical studies in Paris. Fair is fair. A promise is a promise. But letters home told of Marya's deep despair.

In time, Marya moved back to Warsaw to take up another governess position. After that, she returned home, where her father had at last retired. She picked up some private tutoring work and once again advanced her studies through the Flying University, which had grown from just two hundred students to some one thousand. It was then, through a cousin who had studied chemistry, that Marya was given a new opportunity—her first chance to work in a laboratory, where, in the evenings and on Sundays, she learned lessons that would guide her for a lifetime.

This laboratory became Marya's "great joy," a place where she was, as she later wrote, "generally left to [her] self" to conduct the experiments in physics and chemistry that she'd read about in her books. Sometimes she'd get the results she was expecting. Sometimes she wouldn't.

Still, she learned an important lesson: "The way of progress is neither swift nor easy."

To imagine Marya in that laboratory—those quiet Sunday and evening hours, those tubes and glass jars and materials, that notebook by her side—is to imagine a young woman discovering her truest passion.

Her purpose.

The range of her intellectual hunger.

At that time, in the late nineteenth century, the periodic table of the elements was still very much a work in progress. It was a concept that had been developed over time by a number of scientists and finally formalized in 1869 by the Russian chemist Dmitri Mendeleev. Its purpose was to organize pure natural elements according to their atomic weights. This helped scientists test and understand the different elements, their individual properties, and their chemical reactions when combined.

One of Mendeleev's key contributions was to leave gaps within the table—room, in other words, to discover new elements. What could those elements be? Who might discover them? When would it be Marya's turn to find out?

**periodic table of the elements:** an arrangement of chemical elements in order of atomic number
**atomic weights:** the average masses of atoms of particular elements

***An Invitation to Discover***

*Over time, Mendeleev continued to add new elements to the table—elements like gallium and germanium, both named for the homelands of the men who discovered them. In time, the remaining blank spots in the table would serve as an invitation to Marya. She would also continue the tradition of naming elements after homelands.*

Finally, Bronya, who was now on the verge of finishing her degree and about to get married, invited Marya to come live with her in Paris. Now it was Marya's chance to take her turn at the Sorbonne, the great university of higher learning in the heart of Paris.

But after all that wishing and all that sacrificing, Marya hesitated. After all she had been through, did she really want to travel again—leave home again, leave her father, who was getting on in years and clearly exhausted? Did she want to leave Poland, the country she loved? Did she truly deserve the education she had been craving? Did she want to travel for three long days? Did she want to be holed up in a train car so spare that she had to bring her own folding chair so she'd have a place to sit? She'd have to pack her own food and drink, too. And what was her destiny, anyway? What would her future really look like? She couldn't quite imagine tomorrow or the next day.

In the end, she answered her own questions: yes. In November 1891, the barely twenty-four-year-old Marya boarded a train bound for Paris, where she would live with Bronya and her new husband in a second-floor apartment.

She would leave her hard work and her heartache behind.

# 3

## A Woman Among Men

Marya arrived in Paris without children to care for, without the heavy secret of a clandestine education, and without fear of the Russians. She registered herself at the Sorbonne under the more French name *Marie* and became one of twenty-three women among almost two thousand men plunged into the feverish world of classic and cutting-edge science. In the classrooms and the laboratories, pursuing two advanced degrees—the first in physics and the second in mathematical sciences—she learned about gravity, electricity, magnetism, biological chemistry, celestial mechanics, advanced mathematics, and so much more from some of the greatest living minds of the day.

She did all this at great physical cost to herself, for soon she was living alone in a tiny attic room, six long flights of stairs up from the street. The room was heated by a small stove that rarely had enough coal.

---

**clandestine:** done in secret
**magnetism:** the phenomenon of certain metals attracting or repelling each other
**biological chemistry:** the study of the chemical processes in living organisms
**celestial mechanics:** the study of the motions of celestial objects

(Imagine Marie carrying that coal up all six flights herself.) Marie's attic grew so frigidly cold in winter that the basin water sometimes froze, and sometimes, when Marie would lie down after a long day of studies, she had to cover herself with every last bit of clothing she owned so that she might get warm enough to sleep.

Marie slept in the same small room where she ate her meals—buttered bread with chocolate, or tea with eggs, or fruit, or sometimes nothing at all. At times she was so hungry that she would faint from lack of sustenance. She read by the light of an alcohol lamp. Because her own Polish education had been so inconsistent, she had more work to do than the other students to overcome what she called her "deficiency." She filled her days with lectures, reading, equations, formulas, debates, conversations, and time once again in a scientific lab, an environment that increasingly felt like home. Just as she had been in her youth, she was rewarded with top honors. With her curly hair and gray eyes, her remarkable mind and enduring persistence, she became an increasingly well-known figure on the Sorbonne campus.

After Marie had earned her first degree, one of her professors helped her obtain a commission to study

**sustenance:** nourishment, such as food or drink
**alcohol lamp:** a device for producing a controlled flame that uses alcohol for fuel; often used in laboratories
**deficiency:** a lack of something necessary

the magnetic properties of steel. Her world and her connections in the intense world of science were growing. In the spring of 1894, at the home of a scientific colleague, she was introduced to Pierre Curie. Pierre was a scientist already known for his work in crystals and magnetism, his talent for designing new scientific instruments, and his unusual scientific background.

Among other things, Pierre had no interest in working for the established, elite institutions. He'd taken a unique path as a student—working mostly with a tutor, as opposed to attending "regular" schools—and begun university studies at the age of sixteen. Within a few years, he was making important discoveries. In fact, he was becoming a bit of a legend.

***Pierre Curie: Scientist and Inventor***

*When Pierre Curie was twenty-one, he and his older brother, Jacques, discovered something called the piezoelectric effect, which concerns the relationship between the compression of certain crystals and electrical voltage. This discovery led to their invention of a brand-new scientific tool: the piezoelectric quartz electrometer, used to detect very small electrical currents. Later, this tool would become useful in the invention and manufacture of quartz watches and electric lighters, among other things.*

**piezoelectric effect:** the ability of certain materials to generate an electric charge in response to pressure or other physical stress

*By 1894, the thirty-five-year-old Pierre was focused on studying the relationship between heat and the transformation of the magnetic qualities of certain magnetic materials. This field of study led to another brand-new Pierre-designed tool: a much-improved scientific balance.*

*Both the piezoelectric quartz electrometer and the new scientific balance would prove to be key to Marie's later studies.*

The first time Marie saw Pierre, he was standing by a window in the home of their mutual friend. She wasn't looking for love; nor was he. They were two scientists on the verge of knowing more about the world—magnetism, elements, atoms. But the conversation that began that evening continued. At physics clubs. During long walks outdoors. In Marie's tiny room. As the friendship grew, so did Marie's insistence that Pierre finally write up his studies so that he might get his long-delayed PhD.

It was Pierre who proposed that they spend their lives together. Marie wasn't sure. She'd always planned to return to Poland after her studies, to advance her native country in whatever ways she could and to spend more time with her father. She'd never imagined becoming a Frenchwoman married to a Frenchman. Besides, she was independent. She wanted to mark out her own future.

**scientific balance:** an instrument that measures mass with a high degree of accuracy

**atoms:** the smallest particles in which chemical elements can exist

She knew how much love could hurt, how dangerous it could be. And so Marie returned to Poland, leaving Pierre alone in Paris.

Pierre refused to give up on her, on them. In letter after letter, he worked to persuade Marie by mapping out the contours of their shared future. He made proposals. Marie considered. He asked again. She refused. He wrote once more, and at first she conceded, but then again she wasn't sure. Pierre kept writing.

***A Love Letter from Pierre***

*"It would, nevertheless, be a beautiful thing in which I hardly dare believe, to pass through life together hypnotized in our dreams: your dream for your country; our dream for humanity; our dream for science. Of all these dreams, I believe the last, alone, is legitimate. I mean to say by this that we are powerless to change the social order. Even if this were not true we should not know what to do. . . . From the point of view of science, on the contrary, we can pretend to accomplish something. The territory here is more solid and obvious, and however small it is, it is truly in our possession."*

On July 26, 1895, the once Marya Salomea Skłodowska became Madame Marie Curie, citizen of France. She dressed for the occasion in the same plain

**contours:** lines that form the general shape of something
**legitimate:** justifiable or in keeping with accepted standards

blue suit that she would later wear in the laboratory she and Pierre would soon share. The ceremony was held in the town hall of Sceaux, the suburb of Paris where Pierre's parents lived. The two scientists pledged their love to one another but did not exchange rings. The reception took place in a lovely garden at Pierre's parents' house. Just a few friends. Close family. Those who could make the trip to offer their well wishes.

When it was over, Marie and Pierre boarded a train with their brand-new bicycles. Their plan was to cycle from fishing village to fishing village along the coast of Brittany before their married life in science truly began.

# 4

## X Is for Unknown

Home from their honeymoon (and now lifelong converts to the wonders of the bicycle), Marie and Pierre rented a small apartment in Paris and filled it with hand-me-down furniture. Marie tried to learn to cook, begging her sister for recipes and kitchen tricks. She also logged every single daily expense, her habit of taking scientific notes extending to their life at home.

The couple paid for their expenses with Pierre's income as a lab instructor and teacher of a course on electricity—one of the best ever created, according to Marie—as well as Marie's continuing work on magnetism. Marie was also studying for her teaching certificate with the hope of earning extra income by teaching in a girls' secondary school.

In every in-between hour, the Curies pursued their own experimental interests, sharing enthusiasms, news, instruments, and hypotheses as they asked and tried to answer scientific questions.

At the time, Paris was alive—a city infused with art

**hypotheses:** assumptions or proposed explanations that can be tested and proved either true or false
**infused:** filled

and artists, culture and ideas, small cafés and colorful theaters. For Marie and Pierre, the world beyond was especially tantalizing, as scientists around the world continued to make rapid and remarkable discoveries that they shared through papers and talks.

There was, for example, news from the laboratory of German professor Wilhelm Conrad Roentgen. Although his academic career had been plagued by misfortune, Roentgen had single-mindedly pursued his interest in the emissions of light caused by electric currents. On November 8, 1895, he made an unexpected discovery: invisible rays that could pass through all substances except bone and metal. He called these rays *X-radiation*, or *X-rays* for short.

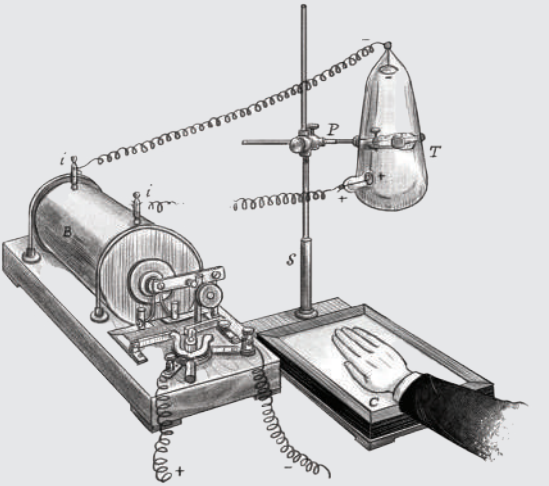
***The X-Ray***

*Roentgen had been using glass bulbs to study cathode rays when he discovered other invisible rays emanating from the bulbs. He first called them* X-radiation *because* x *in mathematics signifies the unknown. These X-rays could somehow pass through many substances, including a person's flesh, but could not pass through bone or metal. Suddenly, doctors could use these X-rays to create images from inside a body—*bone portraits*, some called the phenomenon.*

**cathode rays:** streams of electrons emitted by a negative electrode in a vacuum tube

**phenomenon:** an observable fact or event

*They could see the fracture of a bone or the location of, say, a piece of shrapnel. Poets wrote poems about the X-ray. Scientists experimented. Inventors invented. Marie and Pierre took notice.*




Soon after the discovery of X-rays, the French physicist Antoine Henri Becquerel began to ask himself a question: Could all luminescent materials yield X-rays?

Becquerel, who was also a skilled photographer, used photographic plates to test the effects of sunlight on luminescent uranium salts. He wrapped the plates in dark paper, sprinkled them with uranium salts, and left them out in the sun. The result: The salt crystals emitted

**shrapnel:** metal pieces from an exploded bomb, shell, or other object
**luminescent:** emitting light that is not caused by heat
**photographic plates:** flat pieces of metal or glass coated with a light-sensitive chemical substance
**uranium salts:** chemical compounds consisting of positive uranium or uranium-containing ions and negative ions of other elements or compounds

invisible rays that passed through the dark paper and left outlines of themselves on the photographic plates.

One cloudy day in February 1896, unable to perform the same experiment, Becquerel left his project in a dark drawer. When he went back to retrieve the package, he discovered that the salt crystals had still left a clear outline on the photographic plate—that sunlight, in other words, had not been needed.

Marie was fascinated. This was certainly not the work of an X-ray. It was, instead, a phenomenon yet to be named, one so exciting that Pierre gave up his own research on crystal growth to join Marie's quest for understanding. These mysterious rays would yield a brand-new—and, as it turned out, lifelong—course of shared study.

# 5

## Invisible Rays

In the fall of 1897, Marie gave birth to her first child, a daughter named Irène. She had completed her teaching certificate the previous year, earning the top score on the exams, and was about to publish her first paper summarizing her work on magnetism. Marie decided on her next course of action: the pursuit of a doctoral degree. As she considered what the focus of her degree would be, she couldn't get Becquerel's work out of her mind.

How, Marie wanted to know, did the invisible rays from uranium *work?* With the help of the electrometer Pierre and his brother had invented, she began her experiments. To get to the heart of the matter, she soon realized, she'd need to work with a rock known as *pitchblende*—a rock with enormous potential power.

Some thirty different elements can be found in pitchblende, many of which were already easily extracted and in commercial use in the late nineteenth century. One compound of pitchblende elements known as uranium

**doctoral degree:** the highest academic degree that can be earned from a university

oxide, for example, was commonly used to color glass and pottery a distinctive shade of green.

Marie, however, was interested only in those pitchblende elements that were less known or understood—elements that might explain one of nature's mysteries or even find a place in those gaps in the periodic table. With Pierre's help, she began the work of extracting the materials she would need for her experiments. Marie soon discovered that several other elements appeared to emit the same kind of invisible rays as uranium—and to her shock, one such element seemed to do so even more strongly than uranium did. But looking for that specific element would be like looking for a needle in a haystack.

This was much harder than any governess work. But it was so much more fun and rewarding. Everything had to be done with tremendous care. Every potential consequence of any possible action had to be considered.

To begin with, pitchblende was very expensive. Marie obtained a mere four ounces. She started by grinding down and pulverizing the rock. She then further disintegrated and assayed it with the use of acids and gases. She separated out the known elements like lead and copper. She set aside very tiny but very potent

**pulverizing:** crushing into powder or dust
**assayed:** analyzed

amounts of the lesser-known, mysterious elements to be studied.

Finally, Marie had what she wanted: an element that produced rays nearly four hundred times stronger than those produced by uranium itself. Marie called this element *polonium* in honor of her Polish homeland, and in July 1898, the Curies shared news of their discovery with the world in a scientific publication.

Still, there was more to do, for another powerful element had emerged as a result of all that cracking, grinding, dissolving, testing, and weighing. It, too, exhibited raylike properties. This led the couple to announce, in December 1898, their newest findings. They believed, they wrote, that they had discovered an element they called *radium*—an element that released energy Marie called *radioactivity*.

***Radium (Ra)***

*Radium is an element extracted from pitchblende. As it naturally decays, it releases radioactive rays: energy that can be used for good—for example, in nuclear power, better cancer treatments, and improved ways of measuring the age of the earth—or for harm, including in nuclear weapons. The process of this energy traveling from one place to another is known as* radiation*, and the energy released in this process is called* radioactivity.

For more than three years, the Curies worked with the help of others in a dark wooden shed at the school where Pierre worked or sometimes in the courtyard outside the shed. The place had once been an anatomy theater. Its asphalt floor was hard to stand on for hours at a time. Through its cracked glass roof came the rain and the cold. The worst part, perhaps, was that the place had no ventilation hoods—and the Curies were working with dangerous materials. But this was their passion, their obsession. Their work and their lives were one and the same.

Their hope? To reduce the elements they found to their purest forms. From the mines of Bohemia came heavy bags of pitchblende that had already been depleted of uranium and was therefore considered waste by most. Tons of the stuff. Leave the bags, the Curies said, outside the laboratory door. Then, bag by bag, the Curies would drag the materials in. Using brute force and sophisticated chemical analysis, they continued their work while caring for a baby and themselves, fitting out their inadequate laboratory space with whatever new tools and equipment they could afford, and dealing with

**anatomy theater:** a room often with rising tiers of seats for assemblies (as for lectures or surgical demonstrations)
**asphalt:** a dark, sticky tar-like substance often used to pave roads
**ventilation hoods:** devices hung over stoves or laboratory workstations that use fans to remove harmful substances from the air
**chemical analysis:** the examination of the ingredients that make up a substance

surprising professional disappointments (such as Pierre not getting a Sorbonne professorship in mineralogy he had applied for). They kept tabs on it all in numerous notebooks.

Pierre was beginning to feel deep pains in his bones, especially in his legs and back. Marie's fingertips were burned and numb. But they would not, did not, stop. Finally, Marie succeeded in isolating one-tenth of a gram of pure radium chloride, a heat-giving substance that glowed a beautiful shade of blue at night in its sealed tubes.

**mineralogy:** the study of minerals and their properties

It was, Marie thought, one of the most beautiful things she had ever seen. The work had to continue. And so it did.

***The Nobel Prize***

*The discovery and research of radioactivity was considered so groundbreaking that in 1903, Pierre Curie and Henri Becquerel were nominated for the Nobel Prize in Physics for their work. The unfair omission of Marie's name from the nomination was a deliberate oversight by a male-dominated scientific world. It was corrected only after Pierre insisted that Marie's name be added to the nomination and a well-placed advocate for female scientists took up the cause. When the award ceremony was held in December 1903, Marie was the first woman to ever claim the Nobel honor.*

*The Curies did not travel to Sweden to receive the award, however. Marie had been ill recently, and neither felt up to the long trip through cold weather. They preferred not to leave the lab, Pierre told the committee, and there were, as well, teaching obligations. Only Becquerel appeared in person to accept the award.*

# 6

## Unthinkable Tragedy

Had the Curies wanted to become rich for their many discoveries related to radium, they would have taken out a patent. They did not. Radium was a natural element that, if used appropriately, could benefit humankind. The Curies were only interested in doing the work—in learning more. They wanted, more than anything, to continue decoding the infinite mysteries of hidden minerals.

A better laboratory would have been nice. Perhaps a more stable income and more assistance at home and at work too. But Pierre had finally been named professor of physics at the Sorbonne, and his father had moved in with the family to help out. That was enough for the Curies. Wealth was not a goal. Nor was the fame that was becoming dreadfully inescapable.

There were reporters to deal with now, photographers, strangers banging on their doors, and reams of letters written by radioactivity-loving scientists, inventors, philosophers, and even poets. People expected—

**patent:** an official document that gives an inventor the right to decide who can make, use, or sell their invention

and sometimes demanded—that the Curies give presentations on the power of radium and polonium. They were invited to give talks all around the world. Having gained the respect of the scientific world, the Curies now had less time to do the work that they loved to do.

The Curies' life, Marie complained in a letter to her brother, had been "altogether spoiled by honors and fame."

Seeking solace, time alone, and improved working conditions, the Curies finally moved their work from the old shed to a new laboratory at the Sorbonne. It was little more than an empty room at the start, but it was the promise of a new beginning. It was Pierre's new professorship that had made the lab possible, but the lab's chief of operations, in charge of all experiments and assistants, would be Marie, now pregnant with their second daughter. When Ève was born in December 1904, Marie hired a nurse. Marie continued her work, investigating such matters as the durability and fragility of elements like polonium, that unstable radioactive material with the elusive atomic weight that they had not yet been able to isolate in its purest form.

---

**solace:** comfort in hard times
**durability:** ability to last for a long time
**fragility:** ability to be easily broken or destroyed
**elusive:** hard to find

The following summer, Pierre and Marie were finally feeling well enough to travel to Stockholm, Sweden, to give the speech required by their Nobel Prize honor. Pierre's great respect for his wife's extraordinary scientific mind was clear as he described in detail her contributions to the still-evolving understanding of radioactivity. Pierre spoke of her unwavering determination to prove her hypotheses; her deep curiosity that led to the search for previously unknown radioactive chemical elements; her persistence in the laboratory as she carried out chemical analyses of painstakingly separated minerals; her search, with him, for new radioactive substances; and the discovery, finally, of both polonium and radium.

But there was something else in Pierre's Nobel Prize speech—a warning for the future:

> *Radium rays have been used in the treatment of certain diseases (lupus, cancer, nervous diseases). In certain cases their action may become dangerous. If one leaves a wooden or cardboard box containing a small glass ampulla with several centigrams of a radium salt in one's pocket for a few hours, one will feel absolutely nothing. But 15 days afterwards a redness will appear on the epidermis, and then a sore*

**lupus:** a disease in which a person's immune system attacks their own body
**ampulla:** a rounded bottle with a narrow neck
**epidermis:** the outer layer of skin

*which will be very difficult to heal. A more prolonged action could lead to paralysis and death. Radium must be transported in a thick box of lead.*

*It can even be thought that radium could become very dangerous in criminal hands, and here the question can be raised whether mankind benefits from knowing the secrets of Nature, whether it is ready to profit from it or whether this knowledge will not be harmful for it. The example of the discoveries of Nobel is characteristic, as powerful explosives have enabled man to do wonderful work. They are also a terrible means of destruction in the hands of great criminals who are leading the peoples towards war. I am one of those who believe with Nobel that mankind will derive more good than harm from the new discoveries.*

Before Pierre had time to see what would come of his warnings, tragedy struck. On April 19, 1906, the remarkable collaboration and love story of Marie and Pierre Curie came to a sudden, tragic end.

The family had taken an Easter break, renting a cottage in a small village outside of Paris and spending time enjoying the outdoors. The previous night, after taking the girls home, Marie had joined Pierre, who had returned to Paris two days earlier, for dinner with friends from the Physics Society.

On the fateful day, a Thursday, it rained. Pierre—the pain in his back and legs permanent now, his body exhausted—was returning home from a meeting with colleagues. Seemingly distracted, certainly unaware of his surroundings, and perhaps rushing due to the rain, Pierre stepped out into a busy intersection and directly into the path of a horse pulling a twenty-foot wagon. He fell. One of the wagon's rear wheels shattered his skull. He had calling cards in his pocket, so the police knew at once who the dead man was. Still, it would be hours before Marie received the news.

# 7

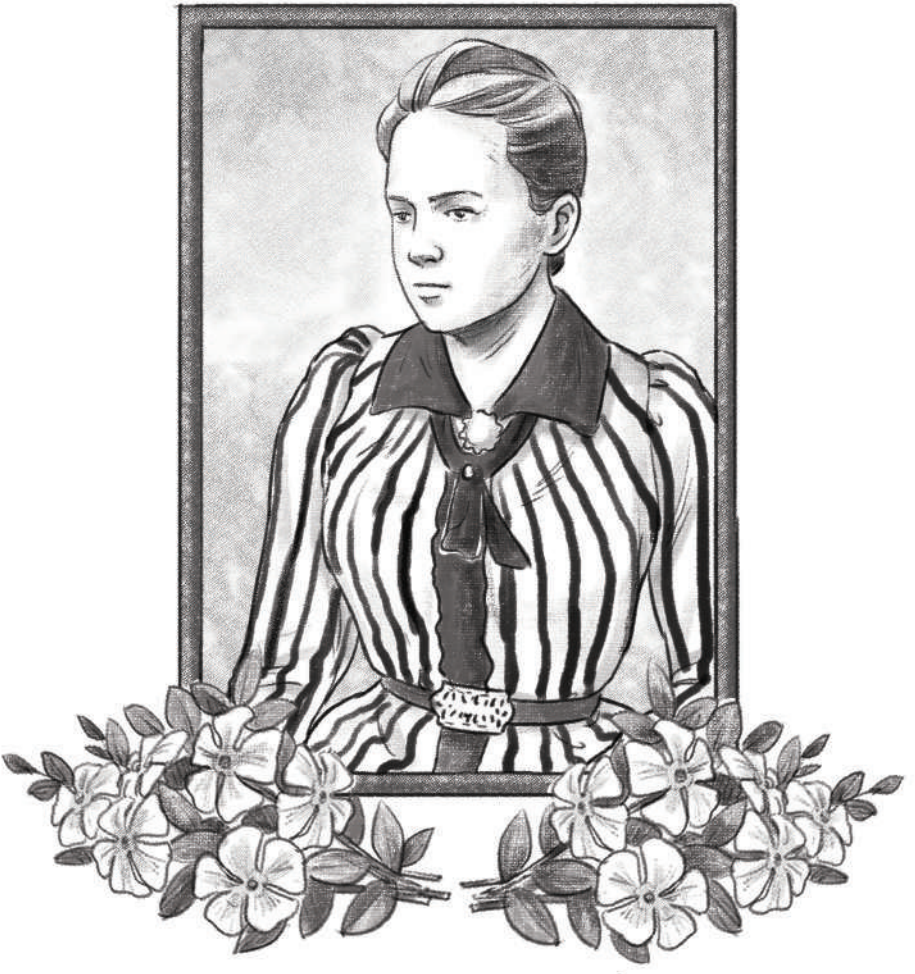
## Periwinkles

Marie had lost the man she deeply loved, the man who had deeply loved her. She'd lost the father of her children, her great collaborator, the man who made certain that the world knew of and honored Marie's own capacities as a researcher and thinker. The man who, just days before, had been vacationing with her in the fresh, open air of a village outside Paris.

The man she had envisioned living and working with for the rest of her life.

In so many ways, the loss was unthinkable. Surrounded by family, unable to explain to Irène and Ève what had happened to their father, Marie laid her husband to rest beside his mother in a graveyard in Sceaux. On his grave, she placed a handful of periwinkles and a photo of herself. In the days that followed, she wrote down everything she could remember about her final days with Pierre in one of her countless notebooks.

She did not want to forget their past. She did not know how to face the future.



# 8

## At the Sorbonne, in the Lab, in the World

Irène was eight. Ève was not yet two. Marie was young, just thirty-eight, but her body felt old, and her heart was pure ache. Still, her daughters needed a mother, and their mother needed a job and a future that would sustain the family.

At the Sorbonne, meanwhile, there was a faculty chair for a professor of physics, left vacant by Pierre. No woman had ever held such a professorship at this university before, but Pierre's former colleagues could think of no better person to continue Pierre's teaching and oversee the laboratory than Marie, who had gained her doctorate in 1903.

She wasn't sure at first. She knew the eyes of the world would be on her, the first woman to ever hold this position. At last she said yes to the invitation, and on November 5, 1906, before a packed auditorium, Madame Curie gave her first lecture on recent advances in physics.

She'd visited Pierre's grave just hours before. She would, as the years passed, take her strength and her inspiration from his memory.

At the laboratory, the work on radioactivity continued under the care of employees and students. Marie's own research continued, too—her quest, for example, to prove that polonium was in fact a new element—as did her conversations and correspondence with other leading scientists of the time.

But Marie's ideas were controversial in some places. Her interactions with others could be sharp, pointed, impatient. There were those who still believed that a woman had no place in this scientific world of mostly men

and those who believed that Marie, who in 1910 put her name forward for nomination to a vacant physicist seat at the French Academy of Sciences, had grown overly ambitious.

And then, in the great loneliness and sadness that set in following Pierre's death, there was the scandal created by Marie's relationship with physicist Paul Langevin. A former student of Pierre's, Langevin was an unhappily married father of four who shared Marie's obsession with physics and experimental science. He was a teacher so brilliant that even Albert Einstein praised his talents.

In 1911, personal letters between the two were leaked to the press, generating terrible headlines and false accusations. Angry mobs gathered outside Marie's door. Her children were confronted by strangers. And all of this was happening at precisely the wrong time, for in that very same year, Marie was nominated for a second Nobel Prize—this one in chemistry, for her discovery of radium and polonium, and this time alone. It was another historic first—a woman, two Nobel Prizes—that threatened to be overwhelmed by the loud voices of the many who felt that the scandal-ridden Marie had no right to accept the award.

Marie refused to let her private life have any bearing on her professional accomplishments. This time, she

would attend the ceremonies and proudly accept her award in person. She traveled to Stockholm with her sister Bronya and her daughter Irène at her side. She stood in that auditorium and delivered her own speech. She declared her role in the discovery of radioactivity as "an atomic property of matter"—a phenomenon capable of helping scientists discover new elements.

But the forces within Marie herself were dwindling. Shortly after her trip to Stockholm, she was hospitalized for a kidney ailment. She was in pain. She was depleted. She was only forty-four years old.

# 9

## The Institute and the War

Before the scandal, before the second Nobel Prize, before the diagnosis that placed Marie under hospital care and sent her searching for cures much like her mother had all those years ago, plans had been put into place to create the Radium Institute.

The plan for a well-funded organization and top-notch laboratory facility reflected Marie's long-held dream of an ideal workspace, state-of-the-art equipment, and deeply qualified research teams. Its purpose would be to help advance knowledge on radioactivity, among other things. In time, several scientists and physicians would be hard at work within its walls on research projects on radium's many uses, including cancer treatment.

Marie would direct the institute. She would continue her own work on isolating those radioactive elements. But in many ways, the point was this: Madame Marie Curie was making room for the next generation of scientists.

***Institut Curie***

*Today, the Institut Curie (French for the Curie Institute), as it became known, has three locations in France. According to its official website, the institute is home to nearly four thousand researchers, doctors, and caregivers who are pursuing its three related missions of "research, care, [and] knowledge transfer." Marie's dream, in other words, has been fully realized.*

In 1914, however, with construction only recently completed, the dream of the Radium Institute could not yet be fully realized. The Great War had broken out, and Paris was changing. Young men were sent off to the battlefields. Refugees flooded the city. The Grand Palais became a military hospital. And while the cafés and theaters remained busy, the threat of war hovered endlessly. The first German bombs fell on Paris at the end of August. War was everywhere, and Marie's attention turned increasingly toward the suffering on the battlefield.

There was, she believed, a role she could play—by knitting, by providing financial aid, and most of all, by putting to work her understanding of X-rays. First, she secured the single remaining gram of radium in France's possession. It had been stored at her institute, but she boarded a train to Bordeaux to lock up this invaluable material in a safer place. Marie then returned to Paris, where she was named director of the Red Cross Radiology Service.

Her first idea was to establish radiology units in hospitals to help diagnose soldiers' wounds. This she did achieve, ultimately creating two hundred stationary units. But her visits to Red Cross hospitals convinced her that something more was needed: mobile X-ray units that could be transported to and used on the front lines of the war. Those would not come cheap.

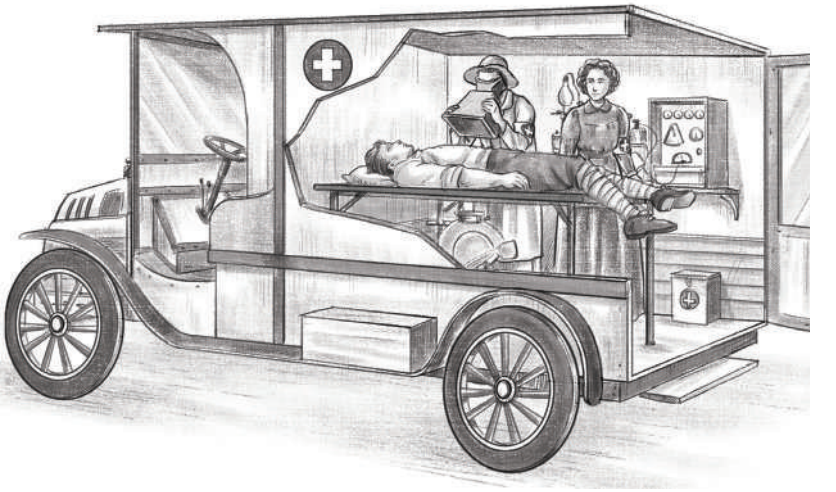
Visiting with the rich, appealing for donations, threatening to melt the gold in her own Nobel Prize medals if necessary, and teaching herself far more than she'd ever known about the science of anatomy—not to mention automobile mechanics—Marie was able to raise the funds and engineer a plan to achieve the near impossible: creating a small fleet of mobile X-ray units. Some of the vehicles were fancy limousines donated by the rich. Some were straight out of the warehouses of automobile manufacturers. All of them had been converted, according to Marie's design, into vehicles of hope and care.

At the same time, Marie, with the help of her seventeen-year-old daughter Irène and others, trained volunteers who wanted to do their part for the soldiers fighting the war. They were given quick tutelage in bone structure and X-rays, which were used to capture

**diagnose:** identify the cause of an illness or other problem
**front lines:** the positions closest to where fighting is taking place

images from inside the body. Doctors working under brutal conditions were now able to locate shrapnel, bullets, and fractures. They could operate with greater precision. They could save lives—hundreds of thousands of lives. Marie did none of this from the safe distance of a laboratory. Indeed, for the first time in her life, Marie got a driver's license. Wearing an old coat, a floppy hat, and a Red Cross band on her arm, she drove across the battlefields in one of the twenty mobile X-ray units that soon became known as *petite Curies*, with Irène often serving as her assistant. Patient by patient, she X-rayed, took notes, and shared her findings with field physicians. She comforted the wounded.

In the end, historians say, Marie Curie's contributions on the battlefield saved some one million lives.



***World War I: The Great War***

*On June 28, 1914, a Serbian nationalist group known as the Black Hand assassinated Archduke Franz Ferdinand of Austria. One month later, Austria-Hungary declared war on Serbia. A large-scale battle soon broke out, involving most European nations as well as Russia, Japan, parts of the Middle East, and, in the end, the United States. The four-year global conflict killed millions of people.*

*The French joined the war quickly. Most men of military age were to report for service by early August 1914. At the same time, refugees from Belgium came to Paris seeking safety. But by early September, the Germans were closing in on the great city.*

*By January 1915, Paris was well defended, and it would remain so until the end of the war. But the war would go on for three more years, ending at last on November 11, 1918, when Germany signed an agreement for peace. It would take years to rebuild from all the ruin.*

# 10

## A Single Gram of Radium

With the war over and many scientists returned home, the world now looked forward. Finally Marie could return to what she loved the most: her laboratory work on the properties of radium. While some continued to shun her and judge her for the choices she had made in her private life, Marie showed up at the institute each day ready to learn, to explore.

She was weak. Her hands hurt. Her heart hurt, too. But this was her obsession and her passion.

In May 1920, Marie granted an interview to an American journalist and socialite named Marie Mattingly Meloney. Mrs. Meloney, who would later describe Marie as "a pale, timid little woman in a black cotton dress, with the saddest face I had ever looked upon," found it impossible to conduct a traditional interview. Instead, she listened as Marie spoke wistfully of the fifty grams of radium that existed in the United States. Fifty grams, and all Marie had in her lab was a single gram.

**socialite:** a person who is well-known in upper-class society

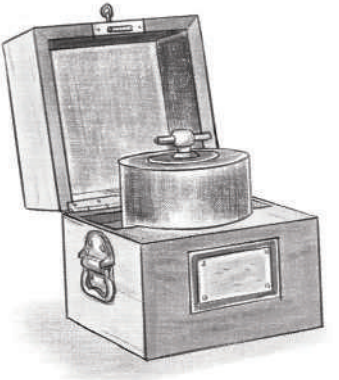
Mrs. Meloney understood that for Marie to continue her experimental work, she would need more radium.

The fact that radium, that rare and difficult-to-extract mineral, was a high-cost item did nothing to dissuade the journalist. One hundred thousand dollars was needed to purchase a gram, and one hundred thousand dollars would be found. Mrs. Meloney set out to raise the money from like-minded American women who held Marie Curie, this brilliant, brave woman operating in a male-dominated world, in the highest esteem. She even published a series of articles that, among other things, exaggerated the possibilities of Marie's research (Marie never claimed, for example, that her radium research would lead to a cure for cancer, but Mrs. Meloney did). The articles made Marie uncomfortable, but they worked. The money was raised.

When the contributions from the many donors were finally tabulated and there was enough to buy Marie her desired gram, Marie traveled with her daughters to the United States for a promised seven-week tour, during which she would be awarded ten honorary degrees, attend countless lunches and dinners, and receive many, many awards. She'd visit a series of women's colleges, whose alumni were among the primary contributors to the radium fund.

**tabulated:** counted

Although given luxury accommodations aboard a ship called the *Olympic*, Marie spent her first several days of travel feeling dizzy and fatigued. Her health remained fragile during the tour. Finally, she arrived in Washington, D.C., where President Warren G. Harding presented her with a symbol of her gift—a golden key that would unlock a mahogany box with a hinged top, into which had been placed a lead cylinder designed to fit ten tiny phials.




Marie had traveled thousands of miles for half a teaspoon of radium.

The radium itself was not present at the White House that day; it was being stored at the National Bureau of Standards until Marie's departure. Marie hung the key by a ribbon around her neck while she continued her travels across the country. She grew wearier by the day. In truth, she could not wait to return to her lab bearing one of the most powerful elements on earth.

**phials:** small, sealed containers, usually made of glass; also called *vials*

# 11

## Final Days

In late June, Marie and her daughters began their journey home. Back at the Radium Institute, a growing number of female scientists were at work alongside their male colleagues, learning the endless things there are to learn about radioactive elements and their properties. Marie had her private workspace at the lab, but she made sure to keep a close watch on her scientists.

She wanted to be certain they were upholding her scientific values. During casual stairway chats, afternoon teas, and private conversations, she reminded them of the principles and ethics of scientific research.

With the help of generous grants, extraordinary scientists, and advancements in the facilities and tools, the institute became a hotbed of discovery and promise. A new radioactive element named *francium* was discovered by an institute scientist named Marguerite Perey. New insights into the structure and workings of the atom made news around the world and changed the nature of the research itself. Government funding and private grants were producing opportunities to greatly advance the diagnosis and treatment of cancer patients.

But the knowledge and understanding of radioactive elements procured by the remarkable scientists of the Radium Institute came at a cost—one that Pierre had warned of and Marie could no longer deny. Sustained exposure to radioactive elements in the lab took its toll. The very element that could help cure cancer patients was also a kind of poison. And many of the workers in the institute had, like Marie and Pierre, been poisoned.

Some had died of diseases that a healthier body would have had the strength to fight. Some had blood cancers.

**francium:** a short-lived radioactive element with the atomic number 87

Some got sick and passed away within just a handful of months. Any hope that exposure to small quantities of the material would not place scientists at risk could no longer be sustained. Enormous new safety measures would be required to protect those who continued the work.

In time, those steps would be taken. But for many in the lab already working with X-rays and radioactivity, and of course for Marie herself, it was too late. For years, her fingertips had been scarred and numb. Her fatigue was famously extreme. Beginning in 1920, cataracts distorted her vision so much that four separate operations on her eyes could not restore it. Marie didn't want anyone to know how deeply she suffered. She did not wish for the public to see her as a victim of her own obsessions.

Marie spent the final years of her life taking care of a body that was failing. But she also spent her time with the daughters she loved and eventually with Irène's growing family. She swam, wrote a book, researched and taught when she could, and grew deeply fond of her granddaughter, Hélène, who would one day become a nuclear physicist.

One day in May, while at work in her laboratory, Marie complained to a colleague of a fever. She went home, never to return to her beloved lab.

**cataracts:** clouding of an eye's lens

Marie Curie died on July 4, 1934, early in the morning. Her daughter Ève was at her side. The diagnosis was aplastic anemia, the result of long exposure to the minerals she had devoted her life to. She was just sixty-six, but her legacy would live on—in the scientific discoveries that continue to launch new ideas and possibilities; in the book her daughter Ève wrote about her life (and in many other books since); in the movies that brought her complex, sometimes bewildering character to life; in the institute that continues in its quest to use scientific discovery for good; and in the legions of girls and young women who have looked to Madame Curie as proof of their proper place in the scientific world.

Today, among many other things, radiation plays a significant role in cancer treatment, helps keep our food safe from harmful bacteria, and is integral to the creation of nuclear power. Its dangers—the power, for example, of an atomic bomb—are also well known. Radiation is, in the end, a force of nature. It is our job, our responsibility, to protect ourselves and others from its harmful properties while making the best use of all its possible and still-emerging good.

It is what Madame Curie would have wanted.

**aplastic anemia:** a disease in which a person's body doesn't make enough blood cells

# Discussion Questions

1. What were some of the challenges Marie faced in her quest to become a respected scientist?
2. If you could meet Marie, what else would you like to know about her life?
3. How would you describe Marie's personality?
4. What do you think Marie would say about the continued development of and use of atomic weapons?
5. What do you think would most surprise Marie about the modern world?
6. What do you think Marie would say are the greatest scientific challenges of our time?
7. What skills do you think are needed to become a scientist?
8. Are there modern scientists that you admire? If so, who are they?
9. Why do you think Marie continued to work with radium even though it was harmful to her?

10. One of Marie's daughters worked alongside her mother. What do you think it was like to have Marie as a mother?

11. What do you think it would be like to grow up in a place where certain learning isn't always encouraged or allowed?

12. Marie lived in a tiny, cold apartment and worked all hours of the day and night. Have you ever experienced discomfort in order to do what you loved?

# Meet the Author

National Book Award finalist **Beth Kephart** is the award-winning author of more than three dozen books in multiple genres, an award-winning teacher of memoir at the University of Pennsylvania, a widely published essayist, and a paper artist. Her new book for adults is *My Life in Paper: Adventures in Ephemera*. Her new book for children is *Good Books for Bad Children: The Genius of Ursula Nordstrom*. More at *bethkephartbooks.com* and *bind-arts.com*.

# Meet the Illustrator

**Kailien Singson.** A born artist, Kailien hails from the northeastern region of India known for its rich natural beauty that serves as a constant inspiration in his work. His passion for art began at a young age with artistic scribbles in notebooks at school, and gradually developed into a serious career that led him to pursue a degree in arts. Having explored several techniques in art through his education and professional years in publishing, Kailien specializes in using striking colors and depicting realistic forms in his work. He is equally adept at traditional art styles, taking inspiration from everyday life.

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