The New Atlantis
A Journal of Technology & Society

The Marvelous Marie Curie

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Marie Curie (1867–1934) is not only the most important woman scientist ever; she is arguably the most important scientist all told since Darwin. Einstein? In theoretical brilliance he outshone her—but her breakthroughs, by Einstein's own account, made his possible. She took part in the discovery of radioactivity, a term she coined; she identified it as an atomic property of certain elements. When scoffers challenged these discoveries, she meticulously determined the atomic weight of the radioactive element she had revealed to the world, radium, and thereby placed her work beyond serious doubt. Yet many male scientists of her day belittled her achievement, even denied her competence. Her husband, Pierre Curie, did the real work, they insisted, while she just went along for the wifely ride. Chauvinist condescension of this order would seem to qualify Marie Curie as *belle idéale* of women's studies, icon for the perennially aggrieved. But such distinction better suits an Aphra Behn or Artemisia Gentileschi than it does a Jane Austen or Marie Curie. Genuine greatness deserves only the most gracious estate, not an academic ghetto, however fashionable and well-appointed.

Yet the fact remains: much of the interest in Madame Curie stems from her having been a woman in the man's world of physics and chemistry. The interest naturally increases as women claim their place in that world; with this interest comes anger, sometimes righteous, sometimes self-righteous, that difficulties should still stand in the way. A president of Harvard can get it in the neck for suggesting that women don't have the almost maniacal resolve it takes to become first-rate scientific researchers—that they are prone to distraction by such career-killers as motherhood. So Marie Curie's singularity cannot but be enveloped in the sociology of science, which is to say these days, feminist politics.

The sociology is important, as long as one remembers the singularity. For Marie Curie did have the almost maniacal resolve to do great scientific work. The work mattered as much to her as it does to most any outstanding scientist; yet can one really say it was everything? She passionately loved her husband and, after his premature death, loved another

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scientist of immense talent, perhaps of genius; she had the highest patriotic feeling for her native Poland and her adopted France, and risked her life in wartime; she raised two daughters, one, Irène, a Nobel Prize laureate in chemistry, the other, Ève, an accomplished writer, most notably as her mother's biographer.

Madame Curie's life reads almost like a comic-book adventure version of feminine heroism: the honest-to-goodness exploits of the original Wonder Woman; the one and only real deal; accept no imitations. Of course, imitation is precisely what such a life tends to inspire in the most zealous and worthy admirers. Madame Curie, however, explicitly warned such aspirants to scientific immortality that the way was unspeakably lonesome and hard, as her daughter Ève Curie records her saying in the 1937 biography *Madame Curie*. "Madame Curie avoided even that element of vanity that might most easily have been forgiven her: to let herself be cited as an example to other women. 'It isn't necessary to lead such an anti-natural existence as mine,' she sometimes said to calm her overmilitant admirers. 'I have given a great deal of time to science because I wanted to, because I loved research.... What I want for women and young girls is a simple family life and some work that will interest them.'" Better for

Radioactive Substances
By Marie Curie
Kessinger ~ 2010 (orig. 1904) ~ 98 pp.
$15.16 (paper)

Madame Curie: A Biography
By Ève Curie
Da Capo ~ 2001 (orig. 1937) ~ 393 pp.
$18.95 (paper)

The Curies: A Biography of the Most Controversial Family in Science
By Denis Brian
Wiley ~ 2005 ~ 448 pp.
$35 (cloth)

Obsessive Genius: The Inner World of Marie Curie
By Barbara Goldsmith
W. W. Norton ~ 2005 ~ 320 pp.
$14.95 (paper)

Radioactive: Marie & Pierre Curie: A Tale of Love and Fallout
By Lauren Redniss
It Books ~ 2010 ~ 208 pp.
$29.99 (hardcover)

Radiation and Modern Life: Fulfilling Marie Curie's Dream
By Alan E. Waltar
Prometheus ~ 2004 ~ 336 pp.
$28.98 (cloth)

gifted women to find some smaller work they enjoy doing and fit it into a life of traditional completeness. But hadn't Madame Curie herself done it all, and on the titanic scale that launched so many dreamers toward the most earnest fantasies, and in many cases the most heartening achievements? How could she warn others off the path she had traveled? Despite her professions that she had taken the course right for her, did she really regret having traveled it?

One can only say that her intensity was preternatural. She could not have lived otherwise than she did: like a demon's pitchfork or an angel's whisper, the need to know, and to be known for knowing—though only among those who mattered, the serious ones like her, for she despised celebrity—drove her on relentlessly. Hardship and ill fortune accompanied her all her days. There seemed to be no ordeal she could not power her way through. Her indomitable will served her voracious intelligence. But for every accomplishment, for every distinction, for every rare joy, she paid and paid. Interludes of happiness brightened the prevailing emotional murk, but the murk did prevail. Episodes of major depression began in childhood and became a fixture. At various times in her life she thought seriously of suicide.

Love could be lost, and forever; children failed to fill the void; only work provided reliable solace and meaning. So she worked. She worked doggedly, devotedly, brilliantly. Scientific work was not simply diversion from the pains of living; it was a way of life, like Socratic philosophy, from which Madame Curie appeared to have acquired the guiding principle: "Nothing in life is to be feared. It is only to be understood." Whether the unforeseen consequences of her work still sustain that sublime credo is a question as yet unresolved.

Early Years in Poland

Maria Salomea Skłodowska was born in Warsaw in 1867, the youngest of five children; she was known as Manya. Her father taught high school mathematics and physics, and her mother was head of a girls' boarding school until her husband's job change made it logistically impossible for her to stay on. Political and personal tragedies clouded Manya's childhood and youth. Since 1815 Poland had been a possession of the Russian empire, and every upstanding Pole hated the foreign overlords. When a Russian school inspector called on the ten-year-old Manya to recite the Lord's Prayer in that reviled tongue and run off the list of recent czars, she responded in perfect order, then broke down in tears at the humiliation

after the official had gone. Every time Manya and her best friend passed a monument to those Poles who faithfully served the Russian regime, they spat in disdain for the filthy collaborators. When Czar Alexander II was assassinated, the two schoolgirls did a victory dance in their empty classroom until they were nailed by their disapproving teacher, who came in unexpectedly. And they kept overnight vigil and prayed at dawn for a friend's brother who was hanged for subversive activity. It would be a long time until Poland breathed free again.

There were even more painful sufferings for the Skłodowska family than living under foreign tyranny. From the time of Manya's birth, her mother had been ill with tuberculosis. The bewildered and heartsick little girl could not understand why her mother pushed her away when she approached for a hug and a kiss. Manya caught on soon enough. The family's evening prayer now included the appeal to restore Madame Skłodowska's health. All too often, such desperate prayers don't take. As her mother grew sicker, Manya prayed that she might die in her place. Instead, her sister Zosia died of typhus. Madame Skłodowska died two years later. Manya was ten.

She continued to make her obligatory Sunday appearances at Mass, but God was now a cruel stranger. The natural reverence of childhood had been kicked out of her. Darkness closed in for a time. She would later call this mournful period "a profound depression," an affliction that would reappear throughout her life, though she would become less forthcoming about the emotional devastation she experienced in her adult years, discreetly referring to her "fatigue" or "exhaustion." As biographer Barbara Goldsmith writes in her compendious, elegant, and sometimes heated 2005 biography, *Obsessive Genius*:

> Today experts would diagnose her condition as a recurring major depressive disorder which is often triggered by grief or loss. It was months before she stopped creeping into deserted spaces and crying, but she hid this from her family and schoolmates. She carried on with her schoolwork with no sign of grief and remained at the top of her class. Soon after her mother's death, Manya seemed to lose herself in books for hours, sometimes days, at a time. She spoke little. The only way she was able to cope was by screening out the world and focusing obsessively on a subject, thus holding at bay her feeling of desolation.

Like her siblings, Manya finished the Russian Gymnasium (high school) heaped with academic honors; she then suffered a thorough nervous breakdown at fifteen, lying in bed all day, virtually mute, starving

herself. A year in the country with more relaxed and contented relatives was exactly what the doctor ordered. She would call it the happiest year of her life: just resting at first, then reading novels, fishing, wandering, picking wild strawberries, going on sleigh rides, receiving gifts from doting uncles, dancing the night away. She seemed an altogether different young girl, perhaps especially to herself. That life could be joyous like this hadn't previously occurred to her.

But seriousness and even solemnity reasserted themselves on her return home. Manya's father had a small salary and had made some bad investments, so the dreams of sending the children abroad to the finest universities evaporated. The young intellectual siblings gave lessons to anyone who would buy them. To be a teacher without a steady job, Manya learned, is to be a flunky, treated with contempt, paid miserably. She persisted in wanting something marvelous but didn't know what. Auguste Comte's positivism—the belief in science's ability to know everything—as refracted through the lens of Polish progressivism—casting off that old-time religion, asserting the equality of the sexes—attracted Manya greatly. She joined the thousands of Polish youth enrolled in the ostensibly clandestine Flying University, a positivist hotbed; the Russian authorities had closed down an earlier incarnation, sending teachers into exile, but it came back stronger than ever, and flourished as an open secret too potent to be suppressed. The studies were glorious, but being a student didn't pay the bills.

Manya found work as governess to a *nouveau riche* Warsaw family whose ostentation and arrogance repulsed her; she lasted a few weeks. Meanwhile, her ambitions and those of her sister Bronya were crystallizing. Bronya was saving to go to the Sorbonne and study medicine, but did not have enough money to cover even the first year of five. Manya, for her part, believed science to be in her future. She promised Bronya that she would work as a governess in the provinces, where room and board were free, and earn enough to put her sister through medical school. Then, when Bronya had set up practice, Manya would follow her to Paris and pursue her own studies.

Manya took a position with the Żórawski family, who managed a sugar-beet estate for rich landowners fifty miles outside Warsaw. The Żórawskis were kind, at least at first, but Manya felt and resented her social inferiority; she refused invitations to parties and shut herself up with mathematics and physics texts in her off-hours. She and one of the Żórawski daughters conspired to teach the local illiterate children how to read and write their native language; such teaching of Polish was punishable by Siberian exile.

Manya's tenure would have been endurable but for one catch: she fell in love with Kazimierz Żórawski, a nineteen-year-old mathematics student at Warsaw University. He fell in love with her, too—though not quite enough to ensure their happiness together. When the young lovers announced to his parents their intention to marry, the elders were furious. A love of this sort was simply not acceptable: a gentleman did not marry a governess. Kazimierz made noises of defiance, but they were sheer bravado: the prospect of disinheritance noticeably diminished his passion for Manya. She longed to quit her job and run but desperately needed the money. Her plunge into "nothingness" and "black melancholy" threatened to become a hopeless free-fall.

A piece of rare luck helped pull her out of it. Her father became director of a reform school, and, though unpleasant, the job paid well enough that he could cover Bronya's way at the Sorbonne. Manya came home. Bronya (one of three women among a thousand medical students) took her degree and married a Polish émigré physician, Kazimierz Dłuski; they set up practice in Paris, and invited Manya to live with them while she took her turn at the Sorbonne. Manya balked. She still dreamed that Kazimierz Żórawski might marry her. But when the couple arranged to meet again at a summer resort, he remained nerveless, and her hopes were dashed for good.

A Marriage of Minds

She had worked to get to Paris—she had worked for almost eight years—and she would have it. But Paris meant even harder work than before. Manya, who now went by the French Marie, had everything to prove. Of 1,825 students in the Faculty of Sciences of the Sorbonne, there were only twenty-three women. She found life at the Dłuskis' too convivial and distracting, and she resented the hour's commute to the Sorbonne, so she took to living on her own in a series of garrets near the university. Lectures, laboratories, and library made up the orbit of her days; when the library closed she studied in her room, sleeping as little as possible. Privation became second nature, anti-natural as it was. In winter the water froze in her washbasin. Her diet was meager fare. A hot meal now and then would have helped, but she did not even know how to cook soup, and learning how would have cut into valuable study time.

Pursuing the life of the mind, she treated her body with contempt, and the protesting body nearly did her in—as it would years later. Overwork and malnutrition caused her to pass out in the library. Her brother-in-law

stepped in and fed her a proper meal, but once she was revived she drove herself to the limit again. Somehow the severity of her life was inseparable from the joy. "All that I saw and learned was a new delight to me. It was like a new world open to me, the world of science which I was at last permitted to know in all liberty." Competition was part of the pleasure of the scientific discipline. She wound up first in her class in physics and second in mathematics. Finishing second grated.

Another turning point in Marie's life came after she found a job studying the magnetic properties of assorted steels for the Society for the Encouragement of National Industry. Inadequate equipment and lab space, however, rendered her efforts feckless, and a Polish professor friend who had known her when she was a governess offered an introduction to the leading French expert on magnetism, who had devised subtle experimental instruments crucial to her work. He was Pierre Curie. Eight years older than Marie, Pierre was still living with his parents at thirty-four, and professed a high-minded revulsion for the charms of women—though he made an exception for women of genius, who were notoriously hard to come by.

His own genius had become apparent early on. When he was twenty-one, he and his older brother Jacques discovered that applying pressure to crystals along their axes of symmetry produces an electric charge: piezoelectricity, the term they derived from the Greek for *to squeeze*. The most exquisite instrument was required to measure the causes and effects, and Pierre invented a "combination of tiny weights, microscopic meter readers, and pneumatic dampeners [that] would become known as the Curie Scale," as one learns from Lauren Redniss's splendid graphic biography and discursive essay, *Radioactive: Marie & Pierre Curie, A Tale of Love and Fallout*. (Every page of the text is set against an illustrated background, with quirky, startling figures often suggestive of ectoplasmic wraiths. The effect is well on the eerie side of lovely, and the combination of talents is impressive.) Piezoelectricity today services the modern technological boomtown; its uses include quartz watches, smoke detectors, electric guitars, tennis rackets, inkjet printers, and fetal heartbeat monitors. Along a separate line of investigation, Pierre also found that magnetism varies with heat; the temperature at which the magnetic qualities of a given substance change is called the Curie Point. Redniss elaborates that "it is used in studying plate tectonics, treating hypothermia, measuring the caffeine in beverages, and understanding extraterrestrial magnetic fields."

Pierre Curie's accomplishments thus far had brought him neither wealth nor glory. He held an unprestigious position at the School of

Physics and Chemistry of the City of Paris—a headfirst fall down the basement stairs from the Sorbonne—and the French government paid him a salary equal to that of a skilled factory hand, as Ève Curie laments in her biography. The lab facilities Marie hoped he might provide her simply did not exist. His wonderful mind, however, was immediately available. His heart opened too in short order. Marie took his romantic ardor under advisement, but she responded to his intellectual passion straightaway with her own. He wooed her intelligence, her sense of vocation. But young Maria Skłodowska's heart was still with her homeland, and she feared that sharing a life with Pierre "consecrated entirely to scientific research" would mean abandoning her country in its time of need. Writing to her while she was on vacation with her father in Poland, Pierre tried to persuade her how "It would be a fine thing…to pass our lives near each other, hypnotized by our dreams: *your* patriotic dream, *our* humanitarian dream, and *our* scientific dream. Of all these dreams the last is, I believe, the only legitimate one."

Pierre proved to the dubious Marie, who had been so badly scorched by love, that he was the only sort of man for a woman like her: a man who lives up to his own ideal of dedication and probity, who disdains the worldly prizes coveted by so many stellar intellects, who does not let himself become small. How could she resist? She had found the man most like herself. Pierre and Marie were married in July 1895 in a simple civil ceremony. In response to a family member's offer to buy her a wedding dress, Ève writes that her mother said that "If you are going to be kind enough to give me one, please let it be practical and dark, so that I can put it on afterwards to go to the laboratory." After the wedding they honeymooned on new bicycles, pedaling away all summer.

The honeymoon over, they set to work with a common will, though the regimen also seemed idyllic to these lovers enamored of science as of each other. In *The Curies* (2005), a detailed, vivid, and lucid account, Denis Brian describes the passion that went into their orderly domestic routine, which is to say decorous romance and labor for the highest ends. In the study of their small bare-bones apartment, the newlyweds sat face-to-face across a white table—no additional chairs for interlopers—and swotted away, often well into the night. Pierre was developing new courses for the School of Physics and Chemistry, and Marie aspiring to teach physics at a new secondary school for girls; naturally she scored the top grade on the exam for would-be teachers. They did find time for Marie to become pregnant, and interrupted another summertime bicycle trip for delivery of their daughter Irène.

Beginnings of a Breakthrough

Soon Marie had bigger things in mind than teaching school. Wondrous new developments in experimental physics entranced her, and she wanted in on the action. Though no women in France had yet done so, Marie intended to get her doctorate in physics. Most of the papers delivered at the Academy of Sciences in Paris were devoted to X-rays, which Wilhelm Röntgen of the University of Würzburg had discovered in 1895. Marie wanted to pursue this hot topic in her dissertation, but Pierre steered her toward a lesser-known one: Becquerel rays.

Working with high-voltage electricity, Röntgen had shot a current through a cathode-ray vacuum tube, and observed a piece of paper, daubed with chemicals in preparation for a later test and lying near the equipment, glow greenish-yellow, but only when the electricity was on. This phosphorescence could not have been caused by any known rays, such as visible or ultraviolet light, since the glass tube was covered with black cardboard that would have contained them. Röntgen had been tinkering—trying something just to see what would happen—and he could hardly believe what he saw. "I did not think. I investigated." His investigations, which kept him virtually sequestered in his lab for seven weeks, showed that these X-rays, named after the mathematical unknown, were produced by the encounter of cathode rays, or streams of electrons, with solid matter, and passed through paper, rubber, and thin sheets of certain metals, though not lead or platinum.

The purely accidental discovery that the rays also penetrated flesh would transform medical practice, and fast. Just weeks after Röntgen's first public lecture on X-rays in 1896, American doctors put the technology to good use, pinpointing the bullet in a gunshot victim's leg, mending a boy's broken arm. Of course, there were those who perceived satanic peril in the discovery, like the distinguished statesman from New Jersey who undertook to ban X-rays as an incitement to public lewdness, and the other American geniuses of the Purity League who wanted a law forbidding X-ray opera glasses.

Serious persons, however, recognized the import of the discovery. When the brilliant French mathematician and physicist Henri Poincaré received from Röntgen his breakthrough scientific paper and photographs of X-rayed hands, Poincaré spread the word in Parisian learned circles almost immediately, and among the physicists fascinated by the possibilities was Henri Becquerel, scion of a notable scientific family. Becquerel surmised that it was not cathode rays from a vacuum tube that produced

X-rays, but that instead the very phosphorescent materials, activated by sunlight, were the point of origin. What he found was different and totally unexpected. He placed phosphorescent uranium salts on a photographic plate, laid the plate on a windowsill so that sunlight could do its work, and developed the plate, on which he could see a dim silhouette of the salts. The sunlight, he reckoned, must be the trigger. To confirm his findings, he next placed a copper cross on the plate with the uranium salts; but there was no sunlight on that rainy February day, so Becquerel swathed his materials in a black cloth and secreted the lot in a drawer to wait for favorable conditions. The rain, however, kept up for days. When he took out the bundle and developed the plate five days later, to his amazement the image of the cross showed clear as could be. Becquerel could not understand what he had found, for science had believed it impossible: spontaneous radiation, coming not from the sun but from an earthly element itself. He figured that some external energy source must have provoked the emission.

The so-called Becquerel rays, with their promise of vast, uncharted scientific territory, enticed the Curies. Not much had been written on the subject, so Marie largely needed to make her own way. Becquerel had found that uranium ionizes the ambient air—causes it to conduct electricity—and Marie set about measuring the intensity of the radiation, using an electrometer of the Curie brothers' invention and a piezoelectric quartz crystal. Denis Brian quotes Marie's 1911 Nobel Prize lecture on the essentials of the experimentation:

> When a uranium compound is placed on a metal plate A situated opposite another plate B and a difference in [electric] potential is maintained between the plates A and B, an electric current is set up between plates; this current can be measured with accuracy… and will serve as a measure of the activity of the substance.

She was describing an elementary Geiger counter. Devising the apparatus took the ingenuity of an experimental wizard, and handling it required the finesse of a master surgeon.

Radioactive Discovery

Marie soon discovered that the intensity of radiation emitted by uranium rays did not depend on its physical or chemical state, but on the amount of uranium, and that therefore the emission was an atomic property of the element. The want of thoroughness can be a gross scientific flaw, but it was not hers: she proceeded to extend her researches beyond uranium,

where most physicists were inclined to stop, and she tested every available element or mineral for what she came to call radioactivity. A few elements were somewhat radioactive; thorium proved more so than uranium.

What really set off her measuring apparatus, though, was pitchblende, a black ore mined on the German-Bohemian border; uranium had already been extracted from the mineral, for use in fine ceramic glazes, so the super-potent radioactivity Marie detected was a mystery, and a trial. Measurements had to be repeated many times to make sure no crucial error had been made. The more Marie measured, the more excited she grew: there had to be a new element here. Pierre shared her excitement, and dropped his own work on crystals to join his wife's project—temporarily, he thought, permanently as it turned out. No other scientists ever took more elaborate pains than they did in seeing their work to completion.

In "Research on Radioactive Substances," her doctoral dissertation, Marie summarized the procedure. With the aid and advice of the chemist Gustave Bémont, the Curies worked to separate out known elements from the pitchblende. Their initial work indeed produced substances many hundreds of times more radioactive than uranium, suggesting the presence of some new, unknown element. Eventually, after months of painstaking work, the Curies were able to purify the substance enough that spectroscopic analysis showed an absorption of wavelengths of light that could not be caused by any previously known elements. This method gave additional evidence for the existence of a new element, which Marie called polonium, after her native country. Within months, the Curies had also discovered radium, which, millions of times more radioactive than uranium, would become her signature achievement. But as Goldsmith writes, the process by which these discoveries were made was as revelatory and far-reaching as the discoveries themselves:

> Her greatest achievement was in employing an entirely new method to discover elements by measuring their radioactivity. In the next decade scientists who located the source and composition of radioactivity made more discoveries concerning the atom and its structure than in all the centuries that had gone before.

At this point, however, her discovery remained incomplete, unfounded, theoretical. As Redniss writes, "It was as if the elements had been grasped only by shadows, and so could be considered no more definitive than, say, the word of a Spiritualist medium." The Curies, along with other Parisian scientific eminences, happened to frequent séances, and speculated that there might be a connection between these mysterious phenomena and

the radiation they were studying. If the Spiritualist professions were true, Pierre wrote, they would be among the most important scientific discoveries ever. Harder heads resisted the claims both of Spiritualism and of the latest physics. Physicists might be inclined to buy what they couldn't see or touch—they believed in rays—but chemists were not so readily convinced. Identifying the elements by their radiation was not the same as isolating and weighing them.

So the ordeal—for an ordeal it was—got underway. After a few months of further work it became apparent that radium would be separated, seen, and weighed more easily than polonium; it also became clear that an immensity of pitchblende was necessary to yield any appreciable amount of radium. The Curies needed more work space, and they needed an open-handed donor to provide them with tons of pitchblende. The Sorbonne, customarily forthcoming with facilities for importunate scientists, turned down their request. The School of Physics and Chemistry could offer the Curies only a former cadaver lab that had fallen into desuetude, broiling in summer, freezing in winter, leaking when it rained or snowed. They took it. Goldsmith cites the disbelief of the Nobel laureate in chemistry Wilhelm Ostwald that anything serious could be accomplished there: "It looked like a stable or potato cellar and if I had not seen the worktable with the chemistry equipment I would have thought it was a hoax." As for the pitchblende, Pierre persuaded the Academy of Sciences of Vienna to convince the Austrian government to give them a virtual mountain of the apparently useless industrial residue for free; he also enlisted Baron Edmond de Rothschild to pay the freight, which the generous and far-sighted Baron did several times over the following four years.

Pierre's executive energy set a formidable industrial enterprise into motion, and they were able to hire workers to help; but the Curies continued to perform onerous and dangerous work. They broke down the pitchblende into its constituent elements, through a series of operations staggering in their physical difficulty and stultifying in their tedium. Their biographers—most vividly in the 1943 biopic *Madame Curie*, based on Ève Curie's book and starring Greer Garson as Marie—show the Curies as harrowed proletarian laborers, toting huge sacks of pitchblende, grinding up ore, stirring the foul and heavy slurry of pitchblende and acid. The toil exacted a severe price. Pierre was suffering bone pain, and Marie showed symptoms of tuberculosis; but neither would rest. Only in 1902 did they finally achieve success, extracting one tenth of a gram of radium chloride, and measuring the radioactive element's atomic weight. Both husband and wife found the glowing blue treasure enchantingly beautiful.

Life sped up vertiginously. In 1903, Marie's thesis earned her the doctorate from the Sorbonne that she had worked harder for than practically any graduate student ever; she was the first woman in France to receive such a degree. Later that year Marie and Pierre, along with Henri Becquerel, were awarded the Nobel Prize in physics for their pathbreaking work on radioactivity. Certain influential scientists did not want to grant Marie a share of the honor. Four French grandees, including three who were very familiar with her work, submitted an official nomination touting Pierre and Becquerel as sole discoverers, for the honor of the fatherland. It was sexism and xenophobia of a scurviness one might expect only from distinguished colleagues and supposed friends. Fortunately, a brilliant and sympathetic Swedish mathematician on the Nobel committee informed Pierre before the fact that his wife was to be left out, and Pierre replied that in that case he would not accept the prize for himself. After much bureaucratic commotion, Marie was added to the list of honorees: insult first, distinction to follow.

Nobel Prizes set things into motion. That the Curies had toiled in such dinginess and obscurity embarrassed even the French. The government endowed a new chair for Pierre at the Sorbonne; only tough negotiation, however, got him a promise of his own laboratory and a position for Marie as head of research. But the lab did not materialize until eight years after Pierre's death.

Meanwhile, radium became all the rage. High-minded devotion to the humanitarian ideals of science decided the Curies against patenting their discovery; but there was no shortage of opportunists hot to cash in. Redniss lists two dozen ailments, from anemia to gastric neurosis to prostatitis, that one purveyor of radium to the credulous claimed to cure. "Radium-laced toothpaste, condoms, suppositories, chocolates, pillows, bath salts, and cigarettes were marketed as bestowers of longevity, virility, and an all-over salubrious flush."

But golden possibilities shone amid the tinsel and hokum. In 1900 Pierre had attached a tube of radium to his arm for ten hours. Ève Curie would write, "To his joy, a lesion appeared." The burn took weeks to heal, and the very severity of the wound paradoxically suggested the good that radium could do, for it promised strong medicine against cancer. The Curies experimented on small animals, and *curiethérapie* soon showed significant success with human patients. However, as Goldsmith points out, until the 1930s pure radium was so scarce and costly that its use against cancer was uncommon. While radium itself has now fallen out of therapeutic favor, radiation therapy is now of course a mainstay of cancer treatment.

Radium presented grave dangers, however. The patent-medicine radium cure-alls were generally diluted hundreds of thousands of times in some bromide or other, but the radioactivity remained uncommonly strong, and it could do immense harm. A prominent American industrialist hooked on the putative restorative powers of the miracle elixir Radithor saw his face cave in from cancer of the jaw. Factory girls in New Jersey painting radium watch dials, who licked their brushes to put a finer point on them, died of radiation poisoning. People who definitely ought to have known better were not careful, and were not immune. Amputation, blindness, and sterility plagued key researchers. The Curies themselves understood that radiation could do serious damage but somehow did not believe it would damage them. The facts proved otherwise, though to the end the Curies did not connect their physical agonies with their mental triumphs. Redniss writes, "The powers of radium with which they were so enamored—Marie had taken to sleeping with a little jar by her pillow—were steadily corroding their bones, straining their breathing, burning their skin. Their entire lab was toxic.... Radioactivity had made the Curies immortal. Now it was killing them."

But before the radiation poisoning had the chance to kill Pierre, he would die in a street accident in 1906, his skull crushed by a horse-drawn cart. Pierre's sudden death gutted Marie. Ève knew as well as anyone the depth of Marie's pain: "From the moment when those three words, 'Pierre is dead,' reached her consciousness, a cope of solitude and secrecy fell upon her shoulders forever. Mme Curie, on that day in April, became not only a widow, but at the same time a pitiful and incurably lonely woman." For the first time in her life, Marie started keeping a diary. Her record of Pierre's funeral registers the heart's desolation: "We wanted to see everything to the end. They filled the grave and put sheaves of flowers on it. Everything is over, Pierre is sleeping his last sleep beneath the earth; it is the end of everything, everything, everything." Indifference to life and death vies with the bitter longing not to be. "In the street I walk as if hypnotized, without attending to anything. I shall not kill myself. I have not even the desire for suicide. But among all these vehicles is there not one to make me share the fate of my beloved?"

Battles and Scandal

When a month after Pierre's death the Sorbonne offered Marie the opportunity to take over his duties—though not yet his professorial chair, an honor that would come two years later—in her diary she informed

her departed husband of her acceptance, which would enable her to continue his work. Her first lecture in his stead, to a packed auditorium that November, was expected to be a tearjerker. In fact it was an emotionless summation of the great leap forward in physics over the past twelve years. Goldsmith observes, "Few noted that her lecture had started at the exact place Pierre Curie's final lecture had left off." To her diary, and to Pierre, Marie confided afterward her persistent despondency; only the duties of motherhood and the hope that her work would live up to his example kept her going.

Detractors would fault the work she did after Pierre's death for its want of originality, and it is true that her most brilliant achievements lay in the past. Still, Goldsmith rightly comes to Marie's defense: she was continuing Pierre's work in a way that he would have appreciated and that the world needed. "One should not think of her in terms of the progressive discoveries of the structure and power hidden inside the atom. Madame Curie and her laboratory were dedicated to 'medical, biological, and industrial research for the peaceful benefit of humanity.'" No one could match her skill in measuring radioactive substances, especially when a particular element could not be isolated, and such measurement was indispensable to the preparation of radium salts and radioactive isotopes, which were indispensable to the developing technology.

Although her principal interests were now practical, she did not shy from a fierce theoretical fight. Lord Kelvin published a letter to the *Times* of London declaring that Marie's radium was in fact a helium compound. This kind of public criticism was beneath a great scientist's dignity, but Lord Kelvin was sharply at odds with Marie over the age of the earth, which he placed at 20 to 50 million years, while her researches in radioactivity and others' studies in the half-life of radioactive elements led her to place it at over twice that. Goaded by the humiliating challenge, she would spend three years obtaining pure radium and working out its atomic weight with uncanny precision. The earth is now thought to be 4.5 billion years old, so her estimates were still very low, but in successfully taking on Lord Kelvin, she dispelled the lingering doubts about her methods and discoveries.

Devoted though she was to her work, and to her two daughters, her unhappiness failed to lift—until 1910, four years after Pierre's death, when she began an affair with the physicist Paul Langevin, a former student of Pierre's who Einstein said was just a step or two behind him in developing the special theory of relativity. The romance would have been perfect if not for the perennial hitch: Langevin was married, and to

a termagant with a penchant for knocking her husband around. When Jeanne Langevin discovered Paul's (latest) infidelity, she threatened to kill Marie unless she cleared out of town. Jeanne stopped short of murder, but she did arrange the theft of compromising letters from the scientists' love nest, sue for divorce, and release the letters to the press.

The timing was especially inauspicious for Marie, who had just been awarded another Nobel Prize, this one in chemistry, for the discoveries of polonium and radium, and for furthering the knowledge of radium. She was the first person to be awarded two Nobel Prizes. But the press could not get enough of the scandal, which for a certain segment of the public besmirched Marie's achievement beyond hope of cleansing. One need not think highly of adultery to be disgusted at the way she was vilified. Redniss bites into the journalistic loathsomeness until the juices spurt:

> Marie was cast as the conniving tramp who had ensorcelled a married man. Worse, she was a dangerous foreigner—a Jew! they shouted, inaccurately. The story was proof, journalist Gustave Téry wrote, that France was "in the grip of a bunch of dirty foreigners, who plunder it, soil it, dishonor it."

Paul Langevin challenged Gustave Téry to a duel, but both men proved too reasonable to open fire.

Meanwhile, all the unseemliness was making the Nobel committee regret its decision. Swedish notables pressured Marie not to come to Stockholm for the award ceremony. Marie faced down the moralizing opposition, stood by the integrity of her work as the only thing that ought to matter to the scientific community, and showed up in December 1911 to accept her prize. But her romance with Langevin was ending, and the strain of events broke her down. She fell into the worst depression of her life. Suicide appeared the most inviting option. She held off with difficulty.

She sought refuge with a woman mathematician friend in England, and pulled out of her personal darkness just as World War I was getting underway. She would return to France and as usual prove heroic, in the service of life even amidst the maddest death-dealing the world had seen up to that time. In the early days of the war, field hospitals had no X-ray machinery; surgeons rooted blindly in torn flesh for bullets and shell fragments, and had to lop off limbs that might have been saved in more civilized surroundings. Madame Curie helped bring civilization to the battlefield: not only did she put together X-ray facilities for Parisian military hospitals, she devised mobile X-ray units—customized touring cars outfitted with the necessary equipment, to be driven to the frontlines

where the wounded could be attended to as promptly as possible. Marie sometimes drove one of the cars and operated the X-ray machinery; her daughter Irène joined her. By the end of the war there were twenty such units, known as "*les petites Curies*," and some had served ten thousand injured men. A million X-rays had been taken overall during the war. Denis Brian notes with blunt scorn, "A grateful French government awarded Irène a Military Medal. It gave Marie Curie nothing."

The Scientist's Honor

Acclaim, and assistance in her work, would come from other quarters in the postwar years. In 1921 the American journalist Marie Meloney drew Curie into a plan to raise money for the purchase of more radium for her Radium Institute in Paris; American scientists and entrepreneurs had a virtual lock on the market, and Madame Curie had been priced out of it. A barnstorming tour of the United States raised more than a hundred thousand dollars, a small fortune at the time, and enough to buy a gram of radium. American generosity responded to Marie's renunciation of personal gain and her devotion to humanitarian service. Honors as well as money for research came her way. Several American colleges granted Madame Curie honorary degrees—though Harvard, which was moving in that direction, ultimately bowed to objections from the antediluvian physics department—and, most astonishing of all, in 1922 the French Academy of Medicine made her its first woman member in its 224-year history. In 1925 she joined Marshal Józef Piłsudski, president of a free Poland, in laying the cornerstone for the new Radium Institute in Warsaw, which her sister Bronya would direct.

But Ève Curie remembered how little pleasure her mother took in all the adulation: "One picture, always the same, dominates the memory of these fêtes and processions for me: the bloodless, expressionless, almost indifferent face of my mother." Marie took a disembodied view of her accomplishment, as though it had been done quite independently of her will, and she endured fame as rather a joke. "In Berlin a crowd on the station platform was bustling and shouting to acclaim the boxer Dempsey, who got out of the same train with me," she wrote. "He looked quite content. After all, is there much difference between acclaiming Dempsey and acclaiming me?" The crowd is always the crowd, but the difference is of course that certain serious people apart from the crowd who didn't know or care about Jack Dempsey revered her; yet not even their esteem brought her joy. Earlier in her career, perhaps, being known by her colleagues as

the first this and the first that was important to her; now only getting her work done in the time she had left mattered.

However, if honor for extraordinary achievement did not really matter anymore, honor in a graver sense mattered very much indeed. Scientists and other brainworkers had the most serious political obligation—to decency above all else. Ève Curie writes that, just as Marie censured the signers of the Manifesto of the Ninety-Three, the group of scientists and intellectuals who glorified German aggression in World War I, so she condemned "the Russian scientists who publicly approved the procedure of the Soviet police: an intellectual betrayed his mission if he was not the most constant defender of civilization and freedom of thought."

Ève, it becomes clear from her book, inherited her mother's sound liberal moderation. But Irène—a brilliant scientist who shared the 1935 Nobel Prize in chemistry with her husband for the synthesis of new radioactive elements—drifted far to the left, and Irène's husband, Frédéric Joliot-Curie, disgraced his record of patriotism in the Resistance by becoming a dupe of the Soviet fantasy machine. He would be dismissed as a potential subversive from his leadership of the French Commissariat for Atomic Energy, and would be awarded the Stalin Peace Prize for his promotion of universal peace, which is to say, Soviet world domination. (Lauren Redniss fumbles the Joliot-Curies' politics with an insouciant blindness to Communist treachery and destructiveness somehow common to artists; it is the one serious blot on her otherwise excellent book. Denis Brian provides a much fuller and very sensible account of these matters.)

As tyrannies of the left and the right looked better and better in the 1920s and 1930s to respectable people, Madame Curie vehemently declared that there was nothing worthy of respect about unconscionable strongmen: she had lived under an oppressive regime, and understood how fortunate the French were still to live in freedom, despite the hard lot of the poor and the often unjust treatment of women, both of which she wanted to see changed. Marie's intelligence extended well beyond the reaches of her scientific specialty. Indeed, she was more than intelligent: she was wise and good.

A Legacy of Dark and Light

Marie Curie's death was brutal. She had long faced the ravages of extended radiation exposure: fevers, cataracts, respiratory distress, running sores on her hands. Aplastic pernicious anemia finished the job. She died on July 4, 1934, at the age of sixty-seven. Photographs taken not long before her

death showed her looking twenty years beyond her age. Tests of radium emanation levels in her coffin, conducted in 1995 when her and Pierre's remains were exhumed for re-interment among the leading national heroes in the Panthéon, suggested that it was not radium that killed her, but rather the X-rays she had absorbed during World War I. She could not have given more to her exalted vocation as investigator and healer.

What would Madame Curie have thought of the long-term ramifications of her discoveries? The manifold medical and industrial uses of radioactive materials would have staggered her, in the best way. The atomic scientist Alan E. Waltar's *Radiation and Modern Life: Fulfilling Marie Curie's Dream* (2004) gives an idea of the vast scope of the technology, which is used in increasing crop production, controlling insect pests, sterilizing medical equipment, developing new drugs, medical diagnosis, cancer treatment, nuclear power, purifying cosmetics, testing soil at construction sites with radiation gauges, measuring automotive engine wear, inspecting aircraft welds through radiography, determining rail stresses, radioisotope thermoelectric generators for spacecraft, luminescent exit signs in public buildings, DNA forensics, carbon dating, enhancing the beauty of precious gems, authenticating rare paintings, and on and on.

And then of course there is The Bomb: nuclear reactions as the threat of planetary incineration derived from Marie Curie's seminal work. Irène Joliot-Curie said her mother would have been simply appalled by the monstrosity to which her discovery had given rise. Who is not appalled by the devastation at Hiroshima and Nagasaki? Yet the matter is not simple: the atomic attacks there may well have averted the far greater loss of life that would have occurred in an American invasion of Japan. And the prospect of a full-out nuclear exchange kept the Cold War from becoming World War III: it is useful to remember that it was the old-fashioned technology that was employed to kill 49 million persons in World War II. Fortunately, the Soviets were evil but not insane; the same cannot confidently be said of the current enemies of civilization in militant Islam. The ultimate consequences of Madame Curie's discovery, then, might prove simply appalling.

Though heavily shadowed at times, the spark she felt as a young girl desperate for knowledge of pure truth was with her to the end. In one of her final appearances, in a 1933 debate on "The Future of Culture" organized by French author Paul Valéry, she spoke of the allure of science almost as a return to innocence, with the magic and derring-do of childhood:

> I believe that science has great beauty. A scientist in the laboratory is not a mere technician; he is also a child confronting natural phenomena

> that impress him as though they were fairy tales.... I also don't think that the spirit of adventure is in danger of disappearing from our world. If I see anything vital around me, it is this very spirit of adventure, which seems ineradicable and is very closely related to curiosity.

What she calls mere "curiosity" may in this light be more aptly described as *wonder*, the kind of wonder that has always animated the effort to know and understand, the sense of wonder that sustained her through fearsome psychic and physical tribulation.

But the truth in science is not all beauty and light; it is simply true. (In fact, as someone whose own youth was quite tragic, Madame Curie seems to be idealizing childhood as well.) At the level of human life, the radioactive behavior of atoms can kill and save and give off an enchanting glow; but at the scientific level they are just doing what they do. Marie's piercing insight into the latter did not and could not expand to foresee all the ways it would be manifested in the former. Such it always is with the geniuses who usher new facts into our store of knowledge where they take on lives of their own.