Marie Sklodowska Curie: The Woman Who Opened The Nuclear Age

by Denise Ham

A new look at a revolutionary scientist's passion for truth, and how she inspired a generation of Americans.

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Marie Sklodowska Curie (1867-1934) in her laboratory.

In my quest to examine the life of Marie Curie, I had the good fortune to rediscover her life's work, particularly her discovery of polonium and radium, and her great discovery concerning the nature of the atom. In this journey, I was happy to become intimately aware that discovery itself, is an issue of passion. It surprised me considerably that my understanding of her work grew enormously, because I simply loved trying to understand that which she discovered. Since my formal education is more than bereft, especially in science, I think that I am fortunate in being able to discover in myself that very passion for knowledge which drives the creative individual to make critical discoveries that transform the physical universe. I have many people to thank for helping me in this project, which took more than a year; foremost, I wish to thank Madame Marie Sklodowska Curie, and say that her life is an inspiration which I have loved.

Part I

A Commitment to Truth

The year 2003 is the 100th anniversary of Madame Curie's first Nobel Prize. In 1903, she, along with her husband, Pierre Curie, and the physicist Henri Becquerel, won the prestigious prize in physics for their joint work in radioactivity. It was only the third year that the prize had been given, and Marie was the first woman to receive it. Eight years later, Marie Curie received an unprecedented second Nobel Prize, this time in chemistry, for her work with radium.

The genius of Marie Curie can best be understood from the standpoint of her commitment to truth. Curie was a friend and colleague of the great Russian scientist Vladimir Vernadsky. Vernadsky spent a great deal of time working in the Paris Radium Institute, which she created in 1914, and ran until her death in 1934. Indeed, our biosphere had been transformed by the creative work of Curie, Vernadsky, Pasteur, and many others—a change imposed upon it via cognition.

Madame Curie's discovery of the radioactive substances radium and polonium, her initial hypothesis on the nature of uranium being a radioactive substance (she was the first to use the term, "radioactivity"), and her correct insight into the power of uranium (and that of all radioactive substances) as derived from the atom itself, was revolutionary. Her hypothesis of the existence of other radioactive substances, and her relentless search for those substances in mountains of discarded pitchblende (a uranium ore), under the most deplorable and hazardous conditions, is the stuff legends are made of—but it is also *true*.

Marie and Pierre Curie's discovery totally transformed the physical universe in which we live. Although it is true (and often repeated) that Marie and Pierre Curie's work in radioactive substances took a toll on their physical well-being, they would not want to be remembered as "victims" or "martyrs" to the nuclear age. They were deeply committed scientists, who loved truth and beauty, who made significant discoveries that alleviated human suffering, and left a legacy to mankind to be cherished forever.

Marie Sklodowska Curie was not simply a great scientist; she was a magnificent human being, and her love of science and her commitment to truth were reflected in her personal character, which was beyond reproach. To understand her commitment to scientific truth, one must understand the passion behind it. A too often misused word, passion is really the emotional guiding principle behind creative discovery. Creativity without passion, does not exist.

Marie and Pierre Curie's work in radioactivity revolutionized science in the late 19th Century. Marie Curie's hypothesis that radiation was "an atomic property" transformed forever how man would view the atom. There are some biographers who have said that this, and only this, was Marie Curie's great discovery, but that is not true. It was only the first step, which she boldly took, in her 36-year odyssey with radioactive substances. In discovering the nature of nuclear power, much of her work was intimately tied to medical research in particular the use of X-rays for diagnosis, and radioisotopes for cancer treatment. The later discoveries in fission, which would prove to be the next step in harnessing the power of the atom for energy production, were later accomplished by her admirer, another woman, Lise Meitner.

The attack against nuclear energy, and the fear of nuclear science by the population today, is an attack against all scientific progress. The irony is almost too funny: Nuclear science was created and developed by the fairer sex! The idea behind the discoveries was to better mankind, by creating new cures for disease, and producing cheap energy for the planet.

Another irony is the fact that the American population had a love affair with Marie Curie. She was invited to this country twice in the 1920s, and millions of women contributed money to buy her a supply of expensive and rare radium for her research. Radium, one of the most radioactive substances, was discovered by Marie back in 1898.

In discovering a new, renewable resource for mankind, progress could be attained. The world's population could thrive. The zero-population growth movement's ideology would be the laughingstock of future generations. The world needs this science, and it needs more scientists of the caliber of Marie Sklodowska Curie who said: "Nothing in life is to be feared—it is only to be understood."

Manya Sklodowska: The Story of Marie Curie's Youth

Manya Sklodowska was the youngest of the five children of Vladyslow Sklodowski and Bronislawa (née Boguska) Sklodowska, born November 7, 1867, in Warsaw, Poland. Since 1795, Poland had been cut up and absorbed into three countries: To the east was Russia (including Warsaw); to the south was the Austrian Empire; and to the west was Prussia. Despite the fact that Poland was not listed on any map of the time, the national identity, language, and culture of Poland never died.

In the 19th Century, there were two uprisings against the Russian masters, the second one launched five years before Manya's birth. During that revolution, thousands were killed, 10,000 Poles were sent to Siberia, and a minority grouping escaped to Paris. Both of Marie's parents had brothers who were sent to Siberia, and one uncle went into exile to France.

Manya's parents were also revolutionaries, but they believed in revolution through ideas. Members of the intelligentsia, the Sklodowskis believed that Poland could become free only through the development of the mind—science—and through much hard intellectual work. Twenty-five years before his youngest daughter's birth, Vladyslow, a teacher of physics and chemistry, wrote a poem in which he exhorts his countrymen to achieve freedom, not by picking up arms, but by achieving freedom in the search for truth:

> Separated, divided, we are individual and helpless, each looking into the future with apprehension, with fear, each preoccupied with his own small worries, each pursuing a fainthearted course on a narrow road.
>
> Our hearts and minds are busy, our souls no longer house great emotion. All we are is cold, dark, silent, barren.
>
> But suddenly, the storm roars, the thunder cracks. The foundation of the world shakes. Satan's powers cringe,

Prof. Sklodowski and his daughters (from left), Manya, Bronya, and Hela, from an 1890 photograph.

agonized, in fear. This is the end of the age of error and of treason.

Let us break this armor of ice that binds our chests Let us begin today, bring stones to build the temple of truth, the temple of freedom. Let our willpower cure our crippled souls. Let our hard work prove to the world, to God, to our country our worth. . . .

"To the future!" Let us lift our glasses, Dear Brother. Let us offer our pain and our lives to that future. Work, love, and live Brothers! [as cited in Quinn 1995]

Vladaslow recognized that an armed revolution against the much stronger Russia, would amount to defeat. Like many intellectuals in Poland, he thought that education of all Poles, armed with science and technology, must be the answer to achieving a secure nation-state. Unlike many European countries, the division of classes in Poland was not by "royal birth," but was based on the educated versus the uneducated. The Sklodowskis and their children, knew that the only route to nationhood was through the elevation of the peasantry by education.

Vladaslow Sklodowski used his children's playtime for pedagogy, educating them in science, mathematics, literature, and poetry. For example, Manya and her father exchanged letters, while she was working as a governess, in which he posed mathematical problems, and she sent her solutions in her answering letters. In nature trips to the Carpathian Mountains, Vladaslow sat with his children, and taught them the scientific phenomenon of sunsets.

More often, he would read poetry and literature to them in one of the five languages he knew, while simultaneously translating the work into Polish. In fact, for a while, Manya, the woman who would become one of the greatest scientists of the 20th Century, seriously contemplated the idea of becoming a writer, or a poet. As the youngest child, she quickly learned to read at the age of four, and entered school two years younger than her peers. She mastered Russian, which was the required tongue at school and in professional life in Warsaw.

The Russian authorities had decided to wipe out any trace of "Polish" identity, so all lessons were taught in Russian. Eve Curie describes in her biography of her mother, *Madame Curie*, how much the Polish children hated this system. There was a conscious conspiracy in Poland between the teachers and students. There were two sets of lessons, and two sets of books in the grammar schools. For example: A lesson in Polish history, spoken in Polish, would be given by a teacher, but if the Russian masters were to suddenly come into the school, a warning signal was communicated, and the "proper" books, would appear, and Russian would be spoken. The penalty for being caught teaching in Polish was a trip to Siberia.

At the age of 16, Manya graduated, receiving the gold medal for finishing first among girls in Warsaw. Her father decided that because of her hard school life, she needed a rest after graduation, and he sent her to the countryside to live with her cousins for a year.

Manya's older brother, Josef, had studied medicine in Warsaw, but no higher education was offered for the young women in Poland, Therefore, when her oldest sister, Bronya, decided to study medicine, her choice was to go to St. Petersburg or France, both of which entailed financial concerns for the family. Years earlier, Father Sklodowski's beliefs had enraged the Russian school bureaucrats, and he was moved from being one of Warsaw's top teachers in high school, to ever lower-paying positions. Also, Mrs. Sklodowska had succumbed to tuberculosis years earlier, so the only paycheck in the household was far from enough to send young Bronya away from Poland to study medicine.

Although Manya Sklodowska also wished to further her studies, she gladly offered to go to work to help put Bronya through school in Paris, thus demonstrating one of the hallmarks of her character, her selflessness and her love of others. Although she was only 17 years old, she decided to work as a governess in a small Polish village, hundreds of miles from Warsaw. She earned 500 rubles a month, which was a hefty sum for a young girl, and her room and board were provided for, so that the bulk of her earnings could be sent to her sister.

Bronya promised Manya that she would take care of her when her turn came to study, and that promise was kept. Throughout their lives, each sister worked tirelessly on behalf of the other. Their devotion was mutual.

Life in the Country

Young Manya's life as a governess, in the town of Szczuki, miles away from her family and the city she loved, were difficult, yet she made the best of it. She devoted herself completely to her young charges, and when she found that she had more than enough time for herself, she suggested to her employer that she give private classes to the local peasant children, who had no school. Her employer agreed that this was the right thing to do, and in defiance of the Russian authorities, who were many miles away, she taught the children *in Polish*.

In letters to her good friend, Kazia, she wrote of her classes:

> . . .I have many hours of lessons with Andzia, I read with Bronka [the two children she is in charge of], and I work an hour a day with the son of a workman here, whom I am preparing for school. Besides this, Bronka and I give lessons to some peasant children for two hours a day. It is a class, really, for we have 10 pupils. They work with a very good will, but just the same our task is sometimes difficult. . . .

In the next letter, three months later, she says:

> The number of my peasant pupils is now 18. Naturally they don't all come together, as I couldn't manage it, but even as it is they take two hours a day. . . . I disturb nobody. Great joys and great consolations come to me from these little children. . . [Curie 1937, p. 68].

A page from Manya Sklodovska's private notebook, written in 1885, with her drawing and a poem of Heine in German.

It was also during this period in Szczuki, that she attempted to educate herself in chemistry. Her employer allowed her to to go the factory library, and the chemist employed there was so impressed that he gave her 20 lessons. However, this was not enough to satisfy her immense curiosity. She wrote to her brother, Josef, in October 1888: "I am learning chemistry from a book. You can imagine how little I get out of that, but what can I do, as I have no place to make experiments or do practical work?"

Manya's Informal Education: Her Teacher Josef Boguska

After spending five years as a governess, Manya returned to Warsaw. During this period in Poland, there existed an "underground" college, known as the Floating University, where young men and women could study with trained individuals. This was especially important for the young women, who had no where to turn for advancement, except to leave the country. The Floating University was run by Polish patriots, who saw this as a pathway to eventual freedom for their nation. Manya and others (including the Polish economist Rosa Luxembourg), were here introduced to philosophy, progressive politics, and to the latest developments in chemistry, physics, and physiology.

Part of this informal education meant going to the Museum of Industry and Agriculture, which, in reality, was a cover for a scientific laboratory, run by Manya's cousin, Josef Boguska. Educated in St. Petersburg under the great Russian scientist Dmitri Mendeleev, Boguska had also worked as a laboratory assistant for Mendeleev.

Mendeleev is the father of the Periodic Table of the elements, and was one of the most advanced intellectuals in the world at that time. More than 10 years later, when Manya Sklodowska had become the great scientist Madame Marie Curie, she would write often to Josef, sharing with him her discoveries. Josef would, of course, be forwarding all this information to St. Petersburg to his teacher. Mendeleev also visited Paris at the time that Marie Curie lived there. Although it is difficult to know if they actually met one another, they certainly were well aware of each other's work.

Laboratories were banned in Poland. During Prof. Sklodowski's entire life as a teacher of science, he never had access to a laboratory. It was at this time of her life, in the Floating University, that Manya fell in love with science and experimental work, and made the decision to become a scientist. In her *Autobiographical Notes,* written in 1923, she said:

> . . . [D]uring these years of isolated work, trying little by little to find my real preferences, I finally turned towards mathematics and physics, and resolutely undertook a serious preparation for future work.

During this period in Warsaw she wrote:

> I had little time for work in this laboratory. I could generally get there only in the evening after dinner, or on Sunday, and I was left to myself. I tried to reproduce various experiments described in the treatises on physics or

> chemistry, and the results were sometimes unexpected. From time to time a little unhoped-for success would come to encourage me, and at other times I sank into despair because of the accidents or failures due to my inexperience. But on the whole, even though I learned to my cost that progress in such matters is neither rapid nor easy, I developed my taste for experimental research during these first trials.

Most important, however, is the method or epistemology that she learned at the hands of her cousin. The ideas of Mendeleev, in particular, the idea that there were a great many elements yet to be discovered was planted in her fertile mind. Mendeleev had predicted the appearance of many new elements, describing in detail where they would appear on the Periodic Table.

To Paris!

One day in 1891, Manya received her dearest wish, when Bronya wrote to her that she must come to Paris. Bronya had met and married a fellow Polish exile, Casimir Dluska. Dluska was also a doctor, and had been forced to flee Poland because of his political activities. In October of that year, Manya arrived in Paris, and entered the Sorbonne (the University of Paris) as a student of physics. In France, she changed her name to the French, Marie. Her plan was to study physics, and return to Poland to be with her beloved father, and to make a revolution with ideas. The Dluskas lived in Paris's famous Latin Quarter, which at that time was filled with Polish exiles and students. They loved the theater, and socialized politically with many of Poland's future leaders. It was here that Marie met the men who would later bow to her as the queen of science. At one event, accompanied by her sister and brother-in-law, she heard a wonderful young Polish pianist, Ignace Paderewski, the future Prime Minister of a new Polish Republic. She also became friends with the young Wojciechovski, who became the President of Poland.

Although Bronya and her husband opened their apartment to Marie, she desired independence. For several reasons she decided to leave their abode. One, was the fact that she found herself socializing to a much greater degree than she wanted to; she wanted to devote herself entirely to study. Second, she wanted to be much closer to the university. She found an apartment in a fifth-floor walk-up, with no heat and no electricity, but much closer to school. Although the rent ate up the little savings she had, she preferred this arrangement. There were times, however, Eve Curie wrote, that her mother had to be carried to the Dluskas because she had collapsed from hunger. Marie Curie's daughter also wrote that her mother had to use every stitch of clothing and all of her furniture to cover her in the dreaded cold of winter. Though these days were certainly difficult, Marie Curie, always spoke of them with happiness.

In 1893, she graduated at the top of her class in physics. The only woman who completed her studies in physics, Marie Sklodowska received what would be considered a masters degree in the United States. The following year, she received a scholarship from Poland, and she graduated second in mathematics. She never forgot the scholarship, and after graduation, she paid back every cent of the money (which was, of course, unheard of). Later, after she became a famous scientist, she personally provided the funds to have a student from Poland study at the Radium Institute every year.

Part II

Life with Pierre Curie

Marie had planned to return to Poland after she received her formal education, but one of the organizations formed after the Franco-Prussian War to promote the cause of French science hired her to do research. The Society for the Encouragement of National Industry wanted her to conduct a study of the magnetic properties of steel. Because she lacked a proper laboratory environment to do these studies, she began to enquire about the use of other facilities.

In January 1894, Polish physicist Jozef Kowalski, a professor at the University of Fribourg, and his new wife, who happened to be in Paris at the time and who had known Marie when she worked as a governess in Poland, suggested a meeting with a French physicist who worked at the School for Physics and Chemistry. His name was Pierre Curie.

Pierre Curie was born on May 15, 1859, the second son of Dr. Eugene Curie, who was himself the son of a doctor. He was a brilliant scientist who was trained, first, by his father, and then with a tutor, as his father believed that Pierre had unusual talents which might be missed by formal schooling. He began his university study at the age of 16, and received the equivalent of a masters degree at age 18. Pierre did not receive his doctorate until after he met Marie, because his financial situation had forced him to become the head of student laboratory work in physics at the Sorbonne. However, Pierre was never one to be concerned with titles. He demonstrated such a commitment to science, that he made many original discoveries, and went on to do his own research at the School of Industrial Physics and Chemistry in Paris, while he taught there. Although the laboratories at the school were not the best, Pierre never complained.

Pierre's brother, Jacques, although several years older, was his best friend and scientific partner for several years. Together, they worked on the piezo-electric effect. (*Piezo* is from the Greek word to press.) In 1880, Jacques and Pierre discovered that when pressure is placed on specific crystals, like quartz, they can create a voltage. In an electrical field, these same crystals become compressed. Armed with this knowledge, the Curie brothers created a new device, the quartz piezo-electroscope or electrometer which can accurately measure very slight electrical currents. Today, this concept has been applied in quartz watches, microphones, and other electronic components. The quartz piezo-electrometer also played a key role in the discovery of new radioactive elements at the hands of Marie and Pierre.

When Jacques left Paris to become the head of mineralogy at the University of Montpellier, Pierre began pioneering work on magnetism. Pierre looked at the effect of temperature changes on magnetism, and saw that some materials change their magnetic properties under different temperature conditions. Today, in honor of Pierre's work, the term

Le Radium

Pierre Curie (1859-1906)

"Curie point" is used to describe the temperature at which these changes take place. Another device named after him is an extremely sensitive scientific balance. Pierre also followed up the work of Louis Pasteur, with his studies on crystal symmetry:

> A still deeper connection exists between Pasteur and the Curies. Pierre Curie himself was a conscious advocate of the Pasteurian ideas in chemistry and biology. His works on the symmetry characteristics of natural processes established a direct relationship between Pasteur's discovery of the molecular dissymmetry of living processes and fundamental questions of inorganic physics. A half century later the Chinese woman physicist, Chien-Shiung Wu, carried out an experiment with beta rays which refers to a fundamental dissymmetry in the processes in the atomic nucleus and continues to supplement the old ideas of Pasteur and Curie [Tennenbaum 1994].

The backgrounds of Marie and Pierre nearly mirror one another in that both had "republican" families. Pierre's father, Dr. Eugene Curie, was a republican, who manned the barricades in the revolution of 1848, and had his jaw shattered by fire from the government troops. Paris was later hit by a cholera epidemic, and while other doctors left the area, Dr. Curie stayed on ministering to the victims. In another revolution in 1871, Dr. Curie allied himself with the republican cause, and turned his apartment into an emergency room to treat those who were wounded. Pierre, at age 12, and his older brother, Jacques, would canvass the streets in the evenings, bringing back the bloodied victims who had fallen in the day's fighting.

Pierre was 35 years old and unmarried when he met Marie. In fact, Pierre had despaired in ever finding a woman who he could share completely his love and devotion to science and humanity. When he was younger, he wrote in his diary:

> Woman loves life for the living of it far more than we do: women of genius are rare. Thus, when we, driven by some mystic love, wish to enter upon some anti-natural path, when we give all our thoughts to some work which estranges us from the humanity nearest us, we have to struggle against women. . . [Eve Curie 1937, p. 120].

The courtship lasted over a year, because Marie had to choose between Pierre and returning to her beloved Poland—her lifelong plan—to teach science, and to be with her now-elderly father. It is the good fortune of humanity that Marie relented, returned to Paris, and married Pierre in July 1895.

The Years of Great Discoveries

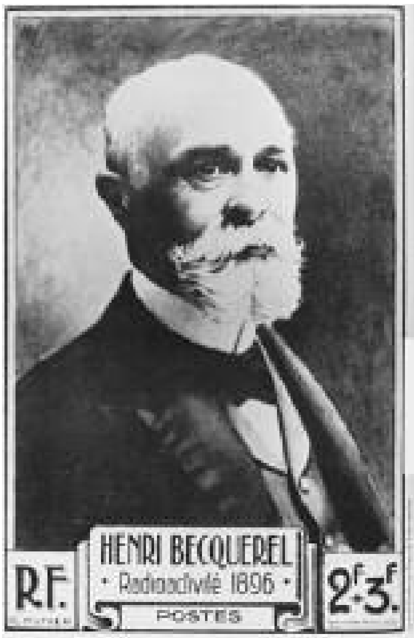
The years 1895 to 1898 were momentous ones for science. First, Wilhelm Roentgen amazed the scientific world with his discovery of X-rays, and so was born the "atomic age" on November 8, 1895. Roentgen took a pear-shaped cathode ray tube, and partially connected it in a circuit. He surrounded this with black cardboard, and after completely darkening the room, he passed a high tension discharge across it. All he wanted to see was whether the black cardboard was able to shield the tube. When he found that it did, he began moving towards his apparatus, in order to continue the experiment, but when he got about a yard from the tube he saw a glimmer of light.

He then lit a match to see from where the light came. What he found, was completely unexpected: he saw the small card coated with barium platinocyanide luminescing, in spite of the fact that it was totally shielded from the cathode ray by a thick sheet of cardboard. When he turned off the tube, the barium-coated card stopped glowing. He turned it on again, and again it glowed.

The next month, he gave a lecture on his discovery. He photographed the hand of the famous anatomist Albert von Koelliker, and when he developed the plate, the old man's bone structure appeared. There was a worldwide shout of applause. In the United States, his experiment was reproduced, and for the first time in history, doctors were able to locate a bullet in a man's leg.

Within a year, there were nearly 50 books and more than 1,000 articles about "Roentgen rays." For the first time since the ancient Greeks, the structure of matter could be analyzed. The old ideas of atoms being solid, impregnable particles, which had been dogma for centuries, was being overthrown.

Everyone in the scientific world rushed with ideas towards a more thorough understanding of X-rays. One of those scientists was the Frenchman, Henri Becquerel. His idea concerned uranium salts. Becquerel thought that when exposed to sunlight, uranium salt crystals, could produce an exposure on a photographic plate, and emit X-rays. In an experiment on February 26 and 27, 1896, he wrapped some photographic plates in black cloth, covered it with a sheet of aluminum, then placed the crystals of potassium uranyl sulphate on top of the aluminum. Because it was cloudy in Paris at the time, and he wanted to see the effect of sunlight on the crystals, he put his experiment in a dark drawer and closed it, to wait for a sunny day. On the following Sunday, he came into work, and saw that the salts had emitted rays onto the photographic plate while it was in the dark. He had discovered radioactivity. It was Marie Curie's job to explain to the world what this phenomenon was, and to discover new radioactive elements.



French postage stamp commemorating Henri Bequerel, who in 1896 discovered natural radioactivity in uranium salts. Bequerel and Pierre and Marie Sklodowska Curie won the Nobel Prize in Physics in 1903 for their work in radioactivity.

The significance of Becquerel's discovery was not immediately acclaimed by many scientists. It was thought interesting, but did not generate much enthusiasm, because it was not understood. Marie and Pierre read Becquerel's paper, and Marie decided to adopt the idea as the basis for her doctoral thesis. Meanwhile, Marie and Pierre had their first daughter, Irène, in September 1897. Irène would follow in her mother's footsteps in science, and she and her husband, Frédéric Joliot, would discover artificial radioactivity, winning the Nobel Prize in Physics in 1935.

Marie began her experiments at Pierre's teaching lab, the School of Physics and Chemistry, with the approval of the director, M. Schützenberger. Pierre had been at the school nearly 15 years, and the kindly director (who was called Papa Schutz) helped the Curies in countless ways.

Marie's plan of attack, was to see whether this property of "radiation" existed in the other known elements on the Periodic Table. Pierre helped her by giving her complete access to his quartz piezo-electrometer, to measure the electrical charge that was known to be emitted from uranium salts. Marie's experiment was to gather all the known elements she could beg from laboratories and university departments, and to put them all to the test. She would put her substance on a small metal plate, opposite another metal plate, which would operate as a condenser. She used the electrometer to see whether there was an electric current in the air between the plates.

She tested all the known elements and minerals, with complete thoroughness, over and over, and shortly found one other element, thorium, which generated electrical activity. Then, she used the electrometer to measure the intensity of the current, and using different compounds of uranium and thorium, she found that what mattered was the amount of uranium present, not whether it was wet or dry, powdered or solid. Marie wrote that radiation energy had a completely different genesis from chemical generation and must come from the atom itself. It was not the interaction of molecules, or new shapes of molecules as in a chemical reaction. In her experiments, she included two minerals, pitchblende and chalcolite, ores from which uranium is extracted.

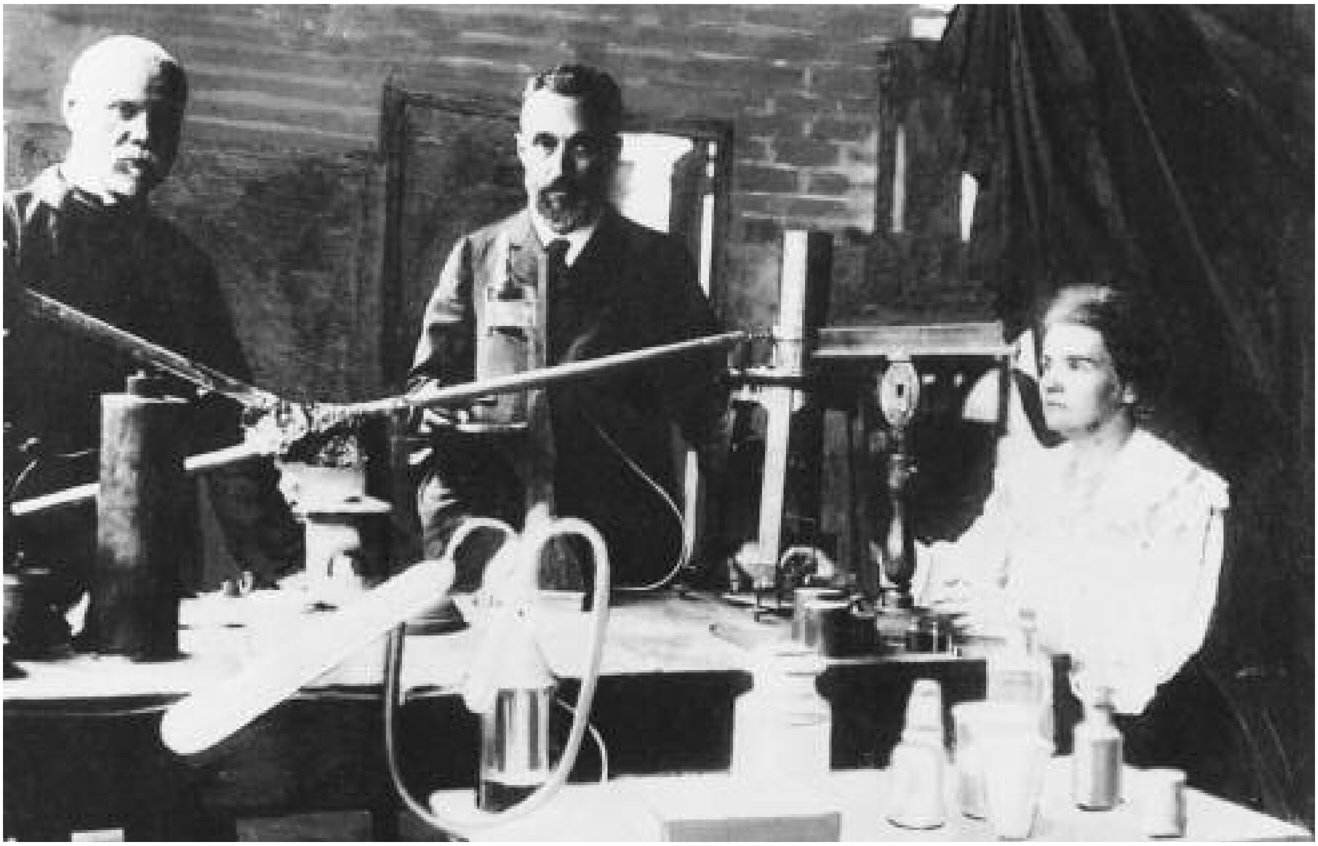
When she measured pitchblende that was devoid of uranium, she discovered that the electrical conductivity was four times greater than that of uranium itself, and that the conductivity of chalcolite was twice as great. This was the paradox she confronted: How could this be possible, since there was no uranium, no thorium present? It is always at critical moments, such as these, that such paradoxes become most exciting for the creative mind. This is what drove Marie to leap boldly onto an hypothesis taking shape in her mind.

> It therefore appeared probable that if pitchblende, chalcolite, and autunite possess so great a degree of activity, these substances contain a small quantity of a strongly radioactive body, differing from uranium and thorium and the simple bodies actually known. I thought that if this were indeed the case, I might hope to extract this substance from the ore by the ordinary methods of chemical analysis [Curie 1961 (1903), p. 16].

Pitchblende is composed of almost 30 elements, and present in this elemental curry, is an extremely powerful radioactive source in a very minute part. How little it actually was, however, would astonish not only the Curies but the whole world. Marie and Pierre initially thought that it could be about 1 percent of the pitchblende. At the end of almost four years, they found that it was less than 1/1,000,000th of 1 percent.

Marie Curie, the scientist, is unlike most any other of her time—and now. Her mind worked like a true Platonic scientist. She was an experimental scientist, who believed first in the primacy of ideas. In January 1904, just after she, Pierre, and Henri Becquerel had won the Nobel Prize for Physics in November 1903, the American *Century Magazine* published an article by her, which leaves no room for doubt of her genius for hypothesis formation, and her rigor for experimental proof.

> The discovery of the phenomena of radioactivity adds a new group to the great number of invisible radiations



Roger-Viollet

Pierre and Marie Curie in their crude "laboratory," an unheated shed in the courtyard of the School of Physics and Chemistry, described by one visiting scientist as "a cross between a stable and a potato-cellar." On the table is Pierre's quartz piezo-electrometer.

> now known, and once more *we are forced to recognize how limited is our direct perception of the world which surrounds us,* and how numerous and varied may be the phenomena which we pass without a suspicion of their existence until the day when a fortunate hazard reveals them. . . .
>
> [Electromagnetic radiations] . . . are present in the space around us whenever an electric phenomenon is produced, especially a lightning discharge. Their presence may be established by the use of special apparatus, and *here again the testimony of our senses appears only in an indirect manner. . .* [*Century Magazine,* 1904, emphasis added].

Towards the end of the article, she presents the world with the fruits of their labor, which began in the winter of 1897, and continued unrelentingly to the day of the article. Although a few other scientists, namely Sir Ernest Rutherford, also knew and understood this newly discovered phenomenon, she would be the major spokesman, for her discoveries of radium, polonium, and actinium (the latter with the help of fellow scientist, André Debierne). All three elements were found in more than 4 tons of pitchblende.

> If we assume that radium contains a supply of energy which it gives out little by little, we are led to believe that this body does not remain unchanged, as it appears to, but that it undergoes an extremely slow change. Several reasons speak in favor of this view. First, the emission of heat, which makes it seem probable that a chemical reaction is taking place in the radium. But this is no ordinary chemical reaction, affecting the combination of atoms in the molecule. No chemical reaction can explain the emission of heat due to radium. Furthermore, radioactivity is a property of the atom of radium; if, then, it is due to a transformation, this transformation must take place in the atom itself. Consequently, from this point of view, the atom of radium would be in a process of evolution, and we should be forced to abandon the theory of the invariability of atoms, which is the foundation of modern chemistry [M. Curie 1904].

In the years before this paper was written, Marie and Pierre had an enormous amount of work to do. First, they wrote to the mine that produced the most active pitchblende that they tested, which belonged to the Government of Austria at Joachimsthal in Bohemia. They were given their first ton of discarded material, and paid the cost of shipping.

They began work in earnest in December 1897, and

Extracting radium in the shed laboratory.

Pierre gave up his research into crystals, in order to help his wife with the project. Pierre involved himself in the physics behind the new substances, and Marie spent most of her time extracting elements from the pitchblende. Each 50 kg of raw pitchblende had to be prepared precisely, and accidents and weather factors sometimes interfered with the process.

The Curies also faced another problem, which is discussed at length in the later part of Marie's thesis: radon gas. The makeshift laboratory in which they worked was contaminated with radon. Although at that time, radon was not yet thoroughly understood, nor even classified as an element, they knew that "emanations" from radium were making their work increasingly difficult. It played havoc with their equipment, and their health.

To understand the whole chemical process, one should read Marie's doctoral thesis, wherein this is described in precise detail. A factory method was organized for each batch of material. Sulphates had to be converted to carbonates. The raw mass was boiled in various concentrations, over and over, to avoid certain chemical processes that would fuse elements and destroy the experiment. They got residues of lead, calcium, silica, alumina, iron oxide, copper, bismuth, zinc, cobalt, manganese, nickel, vanadium, antinomy, thallium, rare earths, niobium, tantalum, arsenic, barium, and so on.

After each separation, Marie devised an elegant chemical procedure known as fractional crystallization. When a solution is boiled and then cools, it causes the formation of pure crystals. For example, if you want to make rock candy, you boil sugar and water, and upon cooling, you end up with the formation of pure sugar crystals (candy). Fractional crystallization is more difficult than making candy, because the chemist must know everything about the elements he is dealing with, the crystals that will form, at what temperature that formation will take place, the atomic weights of the elements that are being boiled, which elements will crystallize first, and so on.

After each element is crystallized, the Curies used the quartz piezo-electroscope to see if there was an electrical charge, which would tell them if they had radioactivity in their batch. The test is repeated over and over, from fractional crystallization, to crystal, to the point where they measured for electrical charge. If the sample has an electrical charge, it may contain a radioactive substance. One element after another was eliminated in this fashion. One thing not known in the beginning to the Curies or to their assistant André Debierne, was that there was more than one radioactive substance in the pitchblende. There were three!

By April 12, 1898, four months after they began, they knew they had found a new element, and they proposed a name for it—polonium. Here are excerpts from Marie Curie's paper, presented to the French Academy of Science by Henri Becquerel:

> Certain minerals containing uranium and thorium (pitchblende, chalcolite, uranite) are very active from the point of view of the emission of Becquerel rays. In a previous paper, one of us has shown that their activity is even greater than that of uranium and thorium, and has expressed the opinion that this effect was attributable to some other very active substance included in small amounts in these minerals. . . .
>
> The pitchblende which we have analyzed was approximately two and half times more active than the uranium in our plate apparatus. We have treated it with acids and have treated the solutions obtained with hydrogen sulfide. Uranium and thorium remain in solution. We have verified the following facts:
>
> The precipitated sulfides contain a very active substance together with lead, bismuth, copper, arsenic, and antimony. This substance is completely insoluble in the ammonium sulfide, which separates it from arsenic and antimony. The sulfides insoluble in ammonium sulfide being dissolved in nitric acid, the active substance may be partially separated from lead by sulphuric acid. On washing lead sulfate with dilute sulphuric acid, most of the active substance entrained with the lead sulphate is dissolved.
>
> The active substance present in solution with bismuth and copper is precipitated completely by ammonia which separates it from copper. Finally the active substance remains with bismuth.
>
> We have not yet found any exact procedure for separating the active substance from bismuth by a wet method. . . .

Re-creating the Curie Experiment to Measure Radioactivity

Roger Ham

"My understanding of Curie's work grew enormously, because I simply 'loved' trying to understand that which she discovered." Author Denise Ham with Paul Frelich, who helped her build this capacitor/electrometer hookup for measuring the radioactive emission from the americium in a smoke detector.

I asked Paul Frelich, a retired electrical engineer, to work with me to re-create the Curie experiment. Originally, I had hoped we could create the exact experiment used by the Curies, but we had to abandon this idea because of the high cost of quartz. Mr. Frelich was kind enough to think through the problem, and create his own version of the Curie experiment, which readers can try. Here is Paul's summary:

The experiment requires the following equipment: (1) Sample holder, (2) Electrometer, (3) Radioactive source, and (4) Power supply.

(1) The sample holder is a neutralizing capacitor that is used in vacuum tube amplifiers. Two circular plates, each $2\frac{3}{16}$ inch in diameter, are held parallel to each other on ceramic insulators. They can be mounted with the plates either horizontally or vertically oriented, and the spacing between the plates can be varied. One plate is fixed in the assembly, and the other fixed to the end of a long screw, which allows the spacing to be varied from zero to $\frac{15}{16}$ of an inch.

In the sample holder shown here, the plates are mounted horizontally. The fixed bottom plate holds the sample, and the upper plate, adjustable in spacing, goes to one pole of the electrometer. A variable potential is applied to the bottom plate.

This neutralizing capacitor assembly is mounted inside a large coffee can, $6\frac{1}{16}$ inch in diameter by $6\frac{1}{8}$ inch high. The can is fitted with a door so that samples can be placed on the bottom capacitor plate.

The purpose of the can is to act as a shield against power line hum, TV, and AM/FM stations, weather radars, and so on. The can is the zero potential reference.

(2) The electrometer is a commercial instrument, Keithley Model No. 260 B, capable of measuring very high resistances and very, very low currents. A shielded cable connects the top plate of the sample holder to the electrometer.

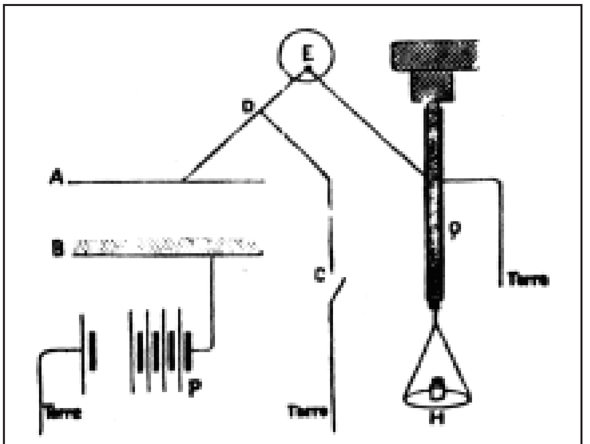
(3) Radioactive source. A smoke-detector was disassembled to obtain the americium, which is rated as a 10-microcurie source. It seems to be a very thin layer or film on a ring: $\frac{1}{4}$ inch in diameter by $\frac{1}{8}$ inch thick with a $\frac{1}{8}$ inch hole in the center containing a rivet, which was used to hold it in the smoke detector. Only the top thin layer is radioactive; the other material is not.

I also selected some samples of granite from a gravel pile at a local construction site, and some samples from an unpaved roadway on a farm in Vermont. Some of these showed radioactivity, and some did not. One sample showed a strong pulsing activity.

(4) Power supply. We originally used a power supply that provided voltages of 0, 10, 25, 75, 300, and 460 volts DC, but this was too heavy to carry around and was dangerous to use at the higher potentials. So, I designed a battery supply that provided 0, and + or – 1.5, 4.5, 9.0, 13.5, and 22.5 volts.

Roger Ham

Closeup of the homemade neutralizing capacitor assembly built inside a coffee can. The sample is placed between the two parallel plates.



M. Curie 1961 [1903], p. 7

Pierre Curie with the quartz piezo-electrometer he invented to measure very slight electrical currents. Later, he and Marie were able to use it to measure radioactivity. Above is a diagram of the piezo-electric device from Marie's thesis. See box (p. 39) for a modern replica of the apparatus.

Finally, we obtained a substance whose activity is about 400 times greater than that of uranium. . . .

If the existence of this new metal is confirmed, we propose to call it polonium from the name of the country of origin of one of us. . . .

With this first great discovery, Marie paid homage to her native land, with the added irony that Poland did not exist on any world map of that time. Isolating polonium, however, was a herculean feat, as it was tightly fused to bismuth. Eugene Demarcay, a close friend of the Curies, possessed a spectroscope and was able to detect a faint spectral line not known to be any other existing element. In 1910, four years after Pierre's death, Marie, along with André Debierne, was able to accomplish this feat. (It took many years because of polonium's short half-life of 135 days!)

In her 1911 Nobel Prize acceptance speech, Marie Curie explained the difficulties:

The stumbling block here is the fact that the proportion of polonium in the mineral is about 5,000 times smaller than that of radium. Before theoretical evidence was available from which to forecast this proportion, I had conducted several extremely laborious operations to concentrate polonium and in this way had secured products with very high activity without being able to arrive at definite results, as in the case of radium. The difficulty is heightened by the fact that polonium disintegrates spontaneously, disappearing by half in a period of 140 days. . . .

Recently, in collaboration with Debierne, I undertook to treat several tons of residues from uranium mineral with a view to preparing polonium. Initially conducted in the factory, then in the laboratory, this treatment finally yielded a few milligrams of substance about 50 times more active than an equal weight of pure radium. In the spectrum of the substance, some new lines could be observed which appear attributable to polonium and of which the most important has the wavelength 4170.5 Å. According to the atomic hypothesis of radioactivity, the polonium spectrum should disappear at the same time as the activity and this fact can be confirmed experimentally. . . .

A similar problem had confronted the Curies earlier, in their discovery of radium, which was announced in a scientific paper on December 26, 1898. At that time, the element barium, chemically similar to radium, was the Gordian knot that had to be untied. Pure radium metal was not produced until just before 1911, the which earned Marie her second Nobel Prize, this time for chemistry. Below are a few highlights of the ground-breaking paper produced by the Curies and Gustave Bémont, an associate of Pierre at the School of Physics and Chemistry. It is considered a gem in classic papers on radioactivity:

The new radioactive substance which we have just found has all the chemical appearance of nearly pure barium: It is not precipitated either by hydrogen sulfide or by ammonium sulfide, nor by ammonia; its sulfate is insoluble in water and in acids; its carbonate is insoluble in water; its chloride, very soluble in water, is insoluble in concentrated hydrochloric acid and in alcohol. Finally this substance gives the easily recognized spectrum of barium.

We believe, nevertheless, that this substance, although constituted in its major part by barium, contains in addition a new element which gives it its radioactivity, and which, in addition, is closely related to barium in its chemical properties.

Here are the reasons which argue for this point of view:

1. Barium and its compounds are not ordinarily radioactive; and one of us has shown that radioactivity appears to be an atomic property, persisting in all the chemical and physical states of the material. From this point of view, the radioactivity of our substance, not being due to barium, must be attributed to another element.

2. The first substance which we obtained had, in the form of a hydrated chloride, a radioactivity 60 times stronger than that of metallic uranium (the radioactive intensity being evaluated by the magnitude of the conductivity of the air in our parallel-plate apparatus). When these chlorides are dissolved in water and partially precipitated by alcohol, the part precipitated is much more active than the part remaining in solution. Basing a procedure on this, one can carry out a series of fractionations, making it possible to obtain chlorides which are more and more active. We have obtained in this manner chlorides having an activity 900 times greater than that of uranium. We have been stopped by lack of material; and, considering the progress of our operations it is to be predicted that the activity would still have increased if we had been able to continue. These facts can be explained by the presence of a radioactive element whose chloride would be less soluble in alcohol and water than that of barium.

3. M. Demarcay has consented to examine the spectrum of our substance with a kindness which we cannot acknowledge too much. . . . Demarcay has found one line in the spectrum which does not seem due to any known element. This line, hardly visible with the chloride enriched 60 times more active than uranium, has become prominent with the chloride enriched by fractionation to an activity 900 times that of uranium. The intensity of this line increases, then, at the same time as the radioactivity; that, we think, is a very serious reason for attributing it to the radioactive part of our substance.

The various reasons which we have enumerated lead us to believe that the new radioactive substance contains a new element to which we propose to give the name of radium.

This announcement was the beginning of a revolution in science. Within just a year of their work, the Curies had discovered two elements, and André Debierne found actinium in the pitchblende sludge. The Curies labored for nearly four more years in producing a tiny bit of radium chloride. The salt was handled by Pierre and Marie, and wrought havoc on their health. Marie's fingertips were burned and cracked. In 1 ton of pitchblende (they worked through about 4 tons under the most primitive conditions), they were able to extract 4 decigrams of radium chloride (about the weight of four postage stamps). Despite the grueling work, they discovered joy and beauty in their results. In her doctoral thesis, completed in 1903, Marie describes the preparation of pure radium chloride:

> The method by which I extracted pure radium chloride from barium chloride containing radium, consists in first subjecting the mixture of the chlorides to fractional crystallization in pure water, then in water to which hydrochloric acid has been added. The difference in solubility of the two chlorides is thus made use of, that of radium being less soluble than that of barium.
>
> At the beginning of the fractionation, pure distilled water is used. The chloride is dissolved, and the solution raised to boiling-point, and allowed to crystallize by cooling in a covered capsule.
>
> Beautiful crystals form at the bottom, and the supernatant, saturated solution is easily decanted. If part of this solution be evaporated to dryness, the chloride obtained is found to be about five times less active than that which has crystallized out. The chloride is thus divided into two portions, A and B, portion A being more active than portion B. The operation is now repeated with each of the chlorides A and B, and in each case two new portions are obtained. When the crystallization is finished, the less active fraction of chloride A is added to the more active fraction of chloride B, these two having approximately the same activity. Thus there are now three portions to undergo afresh the same treatment.
>
> The number of portions is not allowed to increase indefinitely. The activity of the most soluble portion diminishes as the number increases. When its activity becomes inconsiderable, it is withdrawn from the fractionation. When the desired number of fractions has been obtained, fractionation of the least soluble portion is stopped (the richest in radium), and it is withdrawn from the remainder.

Wilhelm Ostwald, a German chemist, once came to visit the Curies after he read about their discovery of radium. He was one of the first men to recognize the importance of what they were doing. The Curies were away on a much needed holiday. Nonetheless, he begged to see their laboratory, and later said:

> It was a cross between a stable and a potato-cellar, and, if I had not seen the worktable with the chemical apparatus, I would have thought it a practical joke [Reid 1974, p. 95].

While Marie worked through ton after ton of pitchblende, eking out the precious bits of radium salt, Pierre worked incessantly on studying the exact nature of radium rays. He passed the rays of radium through magnetic fields, to see how the magnet could deflect rays, and he watched the effects of the rays on different substances, and on chemical reactions. Pierre had stopped his own research into symmetry, to work beside Marie in her arduous task.

In fact, Pierre was the first to hypothesize radium's value in the treatment of cancer. Pierre also boldly experimented with radium on himself: He deliberately burned himself a number of times and tracked the results. Today, one might look with horror on such a dangerous practice, but in the history of medical science a few hundred years ago, such practice was expected. Think of the early practice of vaccination against disease as such an example. It is not difficult to understand why: The work was extremely difficult, and tedious, and it appears that no one else in the scientific world thought it was important enough to devote themselves so fully to the task.

After more than four years, on March 28, 1902, the Curies took their latest sample of radium salts, weighing about .1 gram, to Eugene Demarcay. The powerful rays at first caused his delicate spectroscope to give faulty readings. Demarcay determined that very little barium remained, and the atomic weight given then was Ra = 225.93. Later, Marie was able to refine the radium even further and establish the atomic weight at Ra = 226.

Kelvin and the British Operation against the Curies

In most "established" accounts about Marie and Pierre Curie, there is usually quite a bit of reference to Lord Kelvin and his correspondence with Pierre. In 1892-1893, Pierre Curie was a scientist of little renown inside France. He was an underpaid, overworked, and very humble man. He had quite a few inventions and discoveries, under his belt, but he intensely disliked the limelight of French science, and he consciously avoided seeking a higher position, awards, or accolades for himself. He thought that science was something to be loved for itself, and for the betterment of his fellow man—which might be the reason that he generated such intense interest from the eye of Lord Kelvin.

William Thomson Kelvin (1824-1907) was a ranking member in the British Royal Society. Most of the biographers paint Lord Kelvin as a benevolent elderly scientist. He ingratiated himself with Pierre in Paris, in 1893, and had Pierre build him a quartz piezo-electroscope device for his own use.

Kelvin was an arrogant prig, who said such things as: "There is nothing new to be discovered in physics now. All that remains is more and more precise measurements." He also made predictions, such as, "Radio has no future," and "wireless [telegraphy] is all very well, but I'd rather send a message by a boy on a pony," and "I can state flatly that heavier than air flying machines are impossible"!

Kelvin also imperiously declared that the Earth was not more than 10 million years old. The discovery of radioactivity demolished Kelvin's claim. In fact, as late as 1906—eight years after the discovery of radium, Kelvin still insisted on the indestructibility of the atom. Ernest Rutherford, who had no use for Kelvin, or his proclamations, heard Kelvin speak about radium and said:

> Lord Kelvin has talked most of the day and I admire his confidence in talking about a subject of which he has taken the trouble to learn so little [Reid 1974, p. 112].

Even the so-called immutable Newtonian Laws of Physics, which Kelvin worshipped as if they were his own, came under attack when Pierre announced that radium spontaneously gave off 100 calories/hour in heat. Kelvin proclaimed that this "radium was getting its energy by absorbing mysterious ethereal waves."

In June 1903, Pierre and Marie were invited to London to receive honors from the British Royal Society, and according to biographer Robert Reid, "no doubt Marie would never have been invited to present her own work in her own right" (p. 123). In fact, after Pierre's untimely death, Kelvin attacked Marie in *The Times* of London on August 9, 1906, deliberately avoiding the more appropriate scientific publications for his broadside, by proclaiming that radium was not an element at all. Undoubtedly, he would not have dared to say such a thing while Pierre was alive.

Kelvin's half-baked theory was based on the legitimate work in disintegration theory done by Rutherford and others that radium gives off inert helium gas. Kelvin's hypothesis held that the element lead, also found among the disintegration byproducts of radium, combined with 5 helium atoms—and that was all that radium was. The only reason to take such a theory seriously was that it had the magical name of Kelvin behind it, and was Kelvin's way of attacking Marie's scientific reputation among the uneducated, unscientific world. There was a public battle that emerged from all of this, which not only threatened to ruin Marie's scientific reputation, but also that of any scientist (for example, Rutherford), who did genuine work in understanding radioactive elements.

Marie, who had suffered an enormous emotional blow by the death in 1906 of her beloved husband and scientific companion, was affected by this attack from Kelvin. To prove beyond a shadow of a doubt to everyone in the world that radium was an element, she embarked on another laborious task. Putting all her strength of mind to bear, but this time without Pierre, she labored for almost five years in a tedious process of separating large amounts of radium chloride to produce pure radium metal. Her successful effort captured for her an unprecedented second Nobel Prize, this time for Chemistry.

In her Nobel Acceptance Speech on December 11, 1911, she describes how she, with André Debierne, created radium metal, and she responds to Lord Kelvin:

> Radium has been isolated in the metallic state (M. Curie and A. Debierne 1910). The method used consisted in distilling under very pure hydrogen the amalgam of radium formed by the electrolysis of a chloride solution using a mercury cathode. One decigram only of salt was treated and consequently considerable difficulties were involved. The metal obtained melts at about 700° C, above which temperature it starts to volatilize. It is unstable in the air and decomposes water vigorously.

> The radioactive properties of the metal are exactly the ones that can be forecast on the assumption that the radioactivity of the salts is an atomic property of the radium which is unaffected by the state of combination. It was of real importance to corroborate this point, as misgivings had been voiced by those to whom the atomic hypothesis of radioactivity was still not evident.

A few moments later in her speech, she answered Kelvin and all those who said that radium was merely the combination of other known elements:

> I must remark here that the bold interpretation of the relationship existing between radium and helium rests entirely upon the certitude that radium has the same claim to be a chemical element as have all the other known elements, and that there can be no question of regarding it to be a molecular combination of helium with another element. This shows how fundamental in these circumstances has been the work carried out to prove the chemical individuality of radium, and it can also be seen in what way the hypothesis of the atomic nature of radioactivity and the theory of radioactive transformations have led to the experimental discovery of a first clearly established example of atomic transmutation. This is a fact the significance of which cannot escape anyone, and one which incontestably marks an epoch from the point of view of chemists.

Another scientist who hated Marie Curie, was Sir William Ramsay. He claimed, in a paper he composed in 1913, that it was *he* who had done the first good, accurate work on the atomic weight of radium. Marie, in a letter to her friend Ernest Rutherford, accused Ramsay of "malicious and inexact remarks" about her experiments (Quinn 1995, p. 344).

Also, during this period, she and André Debierne worked together to successfully produce a sample of polonium salt, which proved to be 50 times more radioactive than the same amount of radium. In 1910, at the International Congress of Radiology, held in Brussels, Marie was charged with coming up with an international standard for the measurement of radium. Also at this congress, it was decided to call this unit of radioactivity the *curie*—a measurement that would be standard in hospitals all over the world, where radium was being used in treating cancer.

It is probably no accident that it was at this time, in November 1911, when she was revered by people worldwide, for her discoveries, and thought of as an "angel against death," a conqueror of the most dread disease of the ages—cancer—that the most despicable campaign was launched against her personally. She was attacked publicly in the media for allegedly having an affair with her friend and fellow-scientist, Paul Langevin. Langevin, a student of Pierre Curie, a brilliant scientist, would later discover sonar.

Despite the campaign of slander, Langevin and Marie worked together as close associates at the Radium Institute for the rest of her life. (Marie's granddaughter, Hélène, married Paul Langevin's grandson, Michel. Today, Hélène works at the Radium Institute.)

Marie and Pierre Curie with their daughter Irène, in 1904, after the first Nobel Prize.

Nonetheless, the publicity was so intense, that the very day Marie won her second Nobel Prize, this news was blacked out of the French newspapers, while the so-called affair took top billing. The media accused her of being a "harlot," a "foreigner," and a "Polish Jew." (Marie's family was Polish Catholic, not Jewish, but the press was viciously anti-Semitic; these were the same media that had pilloried Captain Dreyfus, whom Pierre Curie had taken up the pen to defend years earlier.) Marie was called a "dull woman," who "used Pierre's discovery" of radium for her own evil designs. Bricks were thrown against her apartment and her windows were broken.

The unremitting campaign to destroy Marie, forced her to leave the country for a year. Bronya came from Poland, as she had after Pierre's death, and comforted her sister. France came very close to losing Marie, as she thought of moving to Poland permanently. Marie never had any use for the media before this series of events; she was even more emphatic in her disgust with them now.

The Years of Trial and Tribulation

France had come very close to losing both Pierre and Marie, during their critical research into radioactive substances, several years before they honored their nation by winning the Nobel Prize in Physics. The difficulties they faced with the lack of proper laboratory facilities, was compounded by the fact that they were living hand-to-mouth. In 1898, Pierre asked for the chair in Physical Chemistry (Mineralogy), which had become vacant at the Sorbonne. He was known to be the foremost expert in mineralogy in all of Europe. Yet, despite Pierre's vast array of knowledge in the field, the silly politicking among the scientific elite awarded the chair to someone else.

Pierre refused to "play ball" with the establishment. When a scientist was offered an important post, the normal practice was for one to visit all the players, leaving calling cards and gifts. This propitiatory posture was totally repugnant to Pierre. In 1900, the Curies' work with radium and polonium had become well known. Pierre's previous work in crystallography, piezoelectricity, symmetry, and magnetism were also held in high repute. However, all he could obtain was the post of Assistant Professor at the Polytechnique, until he and his wife received a very generous offer from the University of Geneva.

Geneva offered a considerable sum of money, plus a chair for Pierre in physics, coupled with a teaching position for Marie. However, the real temptation was the well-equipped laboratory, plus a second laboratory equipped to Pierre's specifications. They were tempted by this offer, and took a trip to Geneva. In fact, Pierre, at first, accepted the invitation. Pierre's friend, and Marie's teacher, Henri Poincaré, resolved that France would not lose the Curies. Because of Poincaré's influence within the French scientific community, a vacant chair in physics was found at the Sorbonne to counter the Swiss offer, and any obstacles that Pierre might have had were removed by Poincaré.

The result was that France kept the Curies; Pierre was appointed to the newly vacant chair, and Marie was offered a part-time post at the girl's Normal School at Sèvres, teaching physics. No new laboratory came their way, however, and in addition to the posts, came additional responsibilities.

It was a medical pathologist, not a chemist or physicist, who first suggested that the Curies receive a Nobel Prize, and this recognition from the medical community would occur again and again, where Marie was beloved of physicians throughout the world. The pathologist was Charles Bouchard, and his endorsement came in 1901, the first year that a prize in Physics was given. The award was not given until 1903, however, because of the intense politics surrounding giving the award to a woman, or so it appeared. Bouchard was also a foreign member of the Swedish Academy of Sciences, so his nomination of Marie Curie was significant.

It was also necessary to bring in Henri Becquerel as a fellow prize winner, and because the award was not for the discovery of new radioactive substances, there were those who tried to keep Marie's name totally out of the picture. One member of the Swedish Academy of Sciences, Gustav Mittag-Leffler, pushed for the inclusion of Marie. Pierre received a letter from the Nobel Committee on August 6, 1903, telling him that only he had been chosen for the award (Quinn 1995, p. 188). He replied:

> If it is true that one is seriously thinking about me, I very much wish to be considered together with Madame Curie with respect to our research on radioactive bodies. . . . Don't you think it would be more satisfying, from an artistic point of view, if we were to be associated in this manner?

Once again the Academy met, and because of Bouchard's 1901 endorsement, the legal loophole was satisfied, and those who wanted Marie to be part of receiving the award, had the necessary papers to push their cause. Three weeks after Pierre's letter was received, the Nobel Committee decided to give the Prize to both Curies and Becquerel, for "their joint researches on the radiation phenomena."

Marie Curie thus became the first woman to win a Nobel Prize. Despite all the publicity that the award generated, the Curies still did not have access to any new facilities to continue their research. The publicity was decidedly unwanted by the Curies, as they were the subject of continual harassment by the media to give "personal" interviews. They also refused to patent anything connected with their researches into radioactivity, which would have made them very rich people. Simply put, both Pierre and Marie, sincerely believed that their discovery belonged to all of humanity.

Eve Denise Curie, their second child, was born on December 6, 1905, and their family now also included Pierre's elderly widowed father, Dr. Eugene Curie. Dr. Curie loved his grandchildren, and took special care of them when Marie and Pierre were busy teaching, or in the laboratory. Eve recalls her grandfather tenderly: "He had me read many things, memorize poetry of which I understood only half the meaning but of which I felt the beauty. As a result I have always loved poetry very much."

Pierre's Death

On April 19, 1906, Pierre Curie died in a traffic accident. He slipped beneath the wheels of a heavy horse-drawn wagon and was crushed. His death was the most painful experience that Marie Curie would ever know. She was now deprived of her best friend, scientific colleague, and loving husband.

Marie's diary, which was made available to researchers only over the past 10 years, makes plain the extreme sorrow from which she suffered, but Marie was intensely private, and hated melodrama. She suffered alone, and expressed her sorrow only to her sister Bronya, who had come from Poland to be with her. Fifteen years later, Marie Curie was asked to write the biography of her husband. I have excerpted some fragments from her sublime tribute to him:

> I shall not attempt to describe the grief of the family left by Pierre Curie. . . . He was, too, a devoted father, tender in his love for his children, and happy to occupy himself with them. . . .
>
> The news of the catastrophe caused veritable consternation in the scientific world of France, as well as in that of other countries. . . . One of the glories of France had been extinguished. . . .
>
> To honor the memory of Pierre Curie, the French Society of Physics decided to issue a complete publication of his works . . . [which] comprises but a single vol-

Marie with her daughters, Eve and Irène, two years after her husband's death.

ume of about 600 pages, which appeared in 1908, and for which I wrote the preface. One finds in it great richness of ideas and of experimental facts leading to clear and well-established results . . . one might even say classical, in form. . . .

Believing only in the pacific might of science and reason, he lived for the search of truth. . . . Detached from every common passion, seeking neither supremacy nor honors, he had no enemies. . . . [H]e was able to exercise a profound influence merely by the radiation of his inner strength. It is useful to learn how much sacrifice such a life represents. The life of a great scientist in his laboratory is not, as many think, a peaceful idyll. More often it is a bitter battle with things, with one's surroundings, and above all with oneself. A great discovery does not leap completely achieved from the brain of the scientist, as Minerva sprang, all panoplied, from the head of Jupiter; it is the fruit of accumulated preliminary work. Between days of fecund productivity are inserted days of uncertainty when nothing seems to succeed, and when even matter itself seems hostile; and it is then that one must hold out against discouragement. Thus without ever forsaking his inexhaustible patience, Pierre Curie used sometimes to say to me: "It is nevertheless hard, this life that we have chosen. . . . Our society, in which reigns an eager desire for riches and luxury, does not understand the value of science. It does not realize that science is a most precious part of its moral patrimony. Nor does it take sufficient cognizance of the fact that science is at the base of all progress that lightens the burden of life and lessens its suffering. . . ."

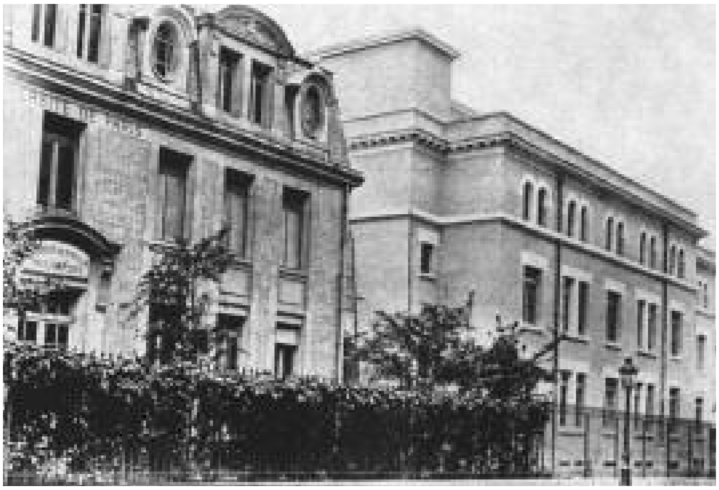
I have wished above all, in gathering together here these few memories, in a bouquet reverently placed upon his tomb, to help, if I can, to fix the image of a man truly great in character and in thought, a wonderful representative of genius of our race. Entirely unfranchised from ancient servitudes, and passionately loving reason and clarity, he was an example "as is a prophet inspired by truths of the future" of what may be realized in moral beauty and goodness by a free and upright spirit, of constant courage, and of mental honesty which made him repulse what he did not understand, and place his life in accord with this dream.

Marie was asked to take Pierre's chair at the Sorbonne. This was an epoch-making event, as she became the first woman in its more than 600-year history to teach there. The amphitheater where she gave her first lesson was packed with reporters, students, professors, and celebrities from the world over. Many expected her to preface her lecture with a tearful tribute to her dead husband. Instead she entered to sustained applause, and simply began her lecture at exactly the point that Pierre had stopped his last lecture. Her sublimity took many by surprise, and it is reported that women and men were drawn to tears by her presence.

The French government offered her a significant annual pension as Pierre's widow, which she refused. She stated that she was 38 years old, healthy, and could work. What Marie really desired was to have a laboratory to continue her work.

During this time, Marie also set up an experimental school, for her daughter and for the children of her close scientific colleagues. Each scientist took turns teaching his specialty, and, as was the case for the Sklodowski children, pedagogy was stressed. The young children quickly mastered scientific subjects, under the elite tutelage. They worked in laboratories along with the parents of their peers, did experiments that most children were able to do only when they reached college. Music was stressed, along with poetry and languages. Marie also saw to it, that a good deal of free time was provided, and that there was plenty of outside exercise, walks, nature observing, and play. Her young daughter, Irène, was able to blossom under such conditions. Eve, although only four years old, began playing the piano, and her mother remarked on more than one occasion that she played with the "understanding" and emotion of an adult.

In 1909, the dream of a laboratory began to take flesh, and not just "a" laboratory, but what would become known as the *Institut du Radium,* the Radium Institute. Another physician, Emile Roux, a champion of Marie, had the idea to create a laboratory under the auspices of the Pasteur Institute, of which he was the head. When this was made public, the Sorbonne decided that it should also support the funding of such an Institute. The idea was to have two main laboratories: one for



The Radium Institute in Paris, completed in 1914, which today has a staff of 1,400 workers.

biology and cancer research, which would be under the auspices of the Pasteur Institute, and the other focussing on the physics and chemistry of radioactive substances, in particular, radium. The latter would be named the Pavilion Curie, in honor of Pierre.

Marie took a direct, active approach, along side the architects, in designing the Radium Institute. When it was finally finished, the words "Institut du Radium, Pavillion Curie" were cut into stone at the entrance. In Eve Curie's biography of her mother, she writes that Marie evoked the beautiful words of Louis Pasteur on the occasion (p. 287):

> If conquests useful to humanity touch your heart, if you stand amazed before the surprising effects of electric telegraphy, the daguerrotype, anesthesia and so many other admirable discoveries: if you are jealous of the part your country can claim in the further flowering of these wonders, take an interest, I urge upon you, in those holy dwellings to which the expressive name of laboratories is given. Ask that they be multiplied and adorned. They are the temples of the future, of wealth and well-being. It is there that humanity grows bigger, strengthens, and betters itself. It learns there to read in the works of nature, works of progress and universal harmony, whereas its own works are too often those of barbarity, fanaticism, and destruction.

Marie planted a garden of rambler roses. Not afraid of physical work, she used the spade, dug up the area, planted trees, and watered them. She was particularly insistent on the idea of aesthetics, and made sure the building was bright, the windows large. Her ardent desire was to create a "beautiful" living space, where people would love to work, a place where, long after she died, people would enjoy its surroundings.

Marie took personal care in every matter regarding the Institute, including the hiring of researchers, and the acceptance of students. She was generous almost to a fault. If a colleague recommended someone, she accepted him or her, without hesitation. She also made sure that women were accepted, as well as foreigners. She personally provided the money for scholarships to poor Polish students to work there. Jonathan Tennenbaum writes in his book, *Nuclear Energy: The Feminine Technology:*

> In this project, [Pasteur Institute director Emile] Roux saw a continuation of the great tradition of Louis Pasteur, who, as a physicist and chemist, introduced a revolution into medicine. The discoveries of Marie and Pierre Curie had cracked open a further, entirely new chapter in science that in the first years already led to a breakthrough in cancer treatment. Particularly fortunate in conjunction with this was the fact that Marie knew how to excellently combine the theoretical with the practical, and in addition possessed an intense personal interest in biology and medicine. . . .
>
> Originally there were places for 50 co-workers. Today the Radium Institute on Rue Pierre et Marie Curie has become a huge complex, with about 1,400 employees. The original buildings are still utilized; in one is found the Curie Museum with the laboratory of Marie Curie and an archive. There one is able to examine the list of the collaborators and visitors over the course of the years. Striking is the great number of women who came to Paris from all corners of the globe in between the two World Wars in order to carry out an "atomic laboratory course" with Marie Curie.
>
> The collaboration between physics, chemistry, biology, and medicine striven after by Roux has proved to be extraordinarily fruitful. It would soon become clear that the Curie Therapy was only the very beginning; the application of radioactive substances permitted researchers and medical doctors to observe and to document living processes in ways that no one had heretofore ever dreamed to have been possible [translated from the German by Edward Carl].

World War I: The Mission to Save Lives

The Radium Institute was barely completed in July 1914, when, on August 1, the French announced the mobilization for war. Marie was vacationing off the coast of Brittany with her children that day, and knew that war was imminent. She left her children in the care of her house-servants and Polish nannies, and went back to Paris. At stake was the precious radium in the Institute's laboratory. While people were fleeing Paris in droves, Marie was making her way back to the city, to make arrangements to personally transport and secure the radium in a bank vault in Bordeaux. But that was not all. Knowing that the nation was thrust into war, she decided to give of herself to her adopted country.

Although many thought that it would be a short war, Marie sensed that the war would be long and brutal. She was proven right. The first casualty reports were 850,000 French killed, wounded, or captured, and 675,000 on the German side. Marie gave her earnings from her Second Nobel Prize, which was in a Swedish bank account, and bought French war bonds to help her country. Eve Curie also reported that Marie offered to give all of her gold medals to the government, to melt them down, but the Bank of France refused to do this. Throughout her life, when she had money, Marie gave generously to Polish aid, national aid, for soldiers, for the poor, and for many other causes.

If the French army had had their way, Marie Curie would not have served her country. When she went to them and proposed her idea of deploying X-ray equipment on the front, they dismissed her; they were so bogged down in fighting, they simply didn't care.

Marie had gotten her idea from a radiologist, Dr. Henri Béclerè, and she was determined to make X-ray equipment the norm on the battlefield. She did some hospital work with Dr. Béclerè, and learned the rudiments of X-ray examination. During this time she visited Red Cross hospitals around Paris, and saw that there was an appalling lack of equipment and personnel. Of course, there was the additional problem, that "at the front" there was no electrical source available to use the X-rays. She thought the problem through and came upon the "radiology car." She put together the car and the equipment, after having found benefactors who would give up their automobiles for that purpose. Among the equipment she had to scavenge for the job are:

> equipment for converting the electricity available on site into the power required, along with several glass vacuum tubes through which the electrical charge would be fired to produce X-rays; a lightweight table on which to lay the patient; a rolling rack for the glass vacuum tube, or ampoule, so that it could be easily moved to the area being examined; a small number of photographic plates and supplies, a screen for radioscopy; curtains to produce darkness at the site; an apron and other material for protecting the operator; and some insulated cable and a few other tools [Quinn 1995, p. 362].

The weight of all the equipment, according to Marie Curie's postwar book on the subject, would come to about 500 pounds. Then there was the problem of electricity. Marie also learned how to maintain and fix the X-ray equipment. She got a driver's license and learned how to fix the car, if needed. Still, the idea of having this equipment made available to surgeons on the front lines was thought absurd, a nuisance, and too dangerous a job for a woman. But Marie was ever conscious of the great numbers of men who were dying, unnecessarily, at the front, because of lack of the proper diagnostic equipment. In her mind, it was criminal to allow this to go on.

From one part of the military bureaucracy to the next, back and forth, she appealed the case, and finally, in late October 1914, she received permission to take her X-ray car to the front. Irène wrote incessantly to her mother, asking to be allowed to come to Paris, and to work alongside her. Marie promised Irène that she could, but only after she was sure that Paris was secure (Paris was bombed in early September). On September 6, 1914, Marie wrote to Irène:

> . . . [T]he theater of war is changing at the moment;

Marie Curie at the wheel of her first mobile radiation unit, which she drove to battlefront hospitals. She mobilized more than 200 of these X-ray cars during the war.

Marie Curie, Irène Curie (standing at right), and students from the U.S. Expeditionary Corps at the Radium Institute in Paris, 1919.

> the enemy seems to be going farther away from Paris. We are all hopeful, and we have faith in the final success. . . . Make young Fernand Chavannes do his problems in physics. If you cannot work for France just now, work for its future. Many people will be gone, alas, after this war, and their places must be taken. Do your mathematics and physics as well as you can [Eve Curie 1937, p. 294].

Both Irène, and little Eve, who was barely 11 years old, missed their mother, who was determined to save the lives of the soldiers. But Irène finally got her wish, and joined Marie when they drove their X-ray car to the front lines on November 1. Irène had taken a crash course in nursing a few weeks before, and passed. Incredibly, despite the fact that Irène worked incessantly during the entire war, she also managed to obtain her certificates from the Sorbonne, “with distinction” in Mathematics (1915), in Physics (1916), and in Chemistry (1917).

Irène was an indispensable help to Marie, both emotionally and scientifically. She very quickly learned the skills to be able to “teach” doctors, who were more than twice her age. Her sister wrote that

> At one hospital she sat down and delivered a brief lesson in elementary geometry to a Belgian doctor who had failed to understand the principles of locating projectiles in the body with the use of radiographs [Eve Curie 1937, p. 235].

Finally together, Marie and Irène, along with a mechanic and chauffeur, went to an Army evacuation hospital at Creil, just behind the front line at Compiegne. This was the first victory in her battle with the military, as Marie fought for the right to be at the front lines all the time.

Another member of the Curie family was also present during this time, Maurice Curie, the son of Pierre’s brother, Jacques. Maurice spent a year in the most dangerous area of the war, Verdun. Marie was afraid for her nephew, and tried to get him reassigned, but he would have none of that. However, as is the case with war, especially the World War I, Maurice became disgusted with the war, particularly with the leadership. He spent month after month confined to trenches, cold and wet, covered with vermin, with little to eat, and frequent tear gassing. In June 1915, Maurice wrote that he was:

> very tired, with a touch of low spirits. . . . I had had more than two months in the trenches in deep winter, and confess that I have a certain apprehension about the new campaign, of which the evidence is palpable [Quinn 1995, p. 372].

By the spring of 1917, the situation had grown so grim that French soldiers were committing acts of insubordination, in protest of the leadership. Marie was saddened by the human carnage she witnessed, as she saw France’s young manhood, with so much promise and potential for good in the future, being destroyed. She was particularly saddened, that so many university students were slaughtered. One youth, Jean Danysz, was a Polish-French Second Lieutenant, and the son of a great biologist who worked with Louis Pasteur. Jean had helped Marie with one of her first radiology cars, and was doing important work on beta rays, which was so impressive that he was offered a position in the United States. But he died in the first year of the war. By the war’s end, 1,375,800 Frenchmen had perished.

Despite the death and destruction, one important advance was accomplished by the doctors and by Marie Curie: Hundreds of young women were trained in radiological science. Dr. Béclerè trained 300 physicians at the Val de Grace Hospital, and Marie directed a course to teach young women to become proficient as radiological technicians at the Radium Institute. Some of the women were nurses, who trained under her, but many were ordinary unskilled young ladies, who wanted to help their country. Some of the women were maids, some were the rich women they served. They all participated in a rigorous course, designed by Marie. Over this two-year period, she gave a basic education in elementary mathematics, physics, and anatomy to 150 young women, who were then sent to staff the hospitals near the front. By the war’s end, Marie had put more than 200 X-ray cars into service and had fought to have more hospitals near the front, which were staffed by trained nurses and technicians. Between 1917 and 1918 alone, 1,100,000 men were treated through these radiological posts.

At the war’s end, Marie published *Radiologie et la Guerre* (Radiology and War), praising the work of these young women. Marie later described an occasion where a female assistant radiologist

> who had only been in the hospital a short time, located the position of a piece of shrapnel which had passed through, and crushed the femur of a man’s thigh. The surgeon . . . did not want to probe for the shrapnel from the side from which the radiologist indicated it was accessible; instead, he probed from the open wound side. Finding nothing, he decided to explore the region indicated by the radiological examination and immediately extracted the shrapnel [Eve Curie 1937, p. 234].

The woman, who went unnamed in this section of Marie’s *Radiology and War* was Irène. Marie did not mention Irène, by name, once in her book, nor did she need to; she brought Irène into the Radium Institute where the two worked together for the rest of Marie’s life. Later, Marie saw her daughter marry another brilliant young student, Frédéric Joliot. In 1935, one year after Marie’s death, Frédéric and Irène Joliot-Curie won the Nobel Prize in Physics, for the discovery of artificial radioactivity.

Part III

Marie Curie and the Physicians of America

On May 20, 1921, the East Room of the White House was filled with more than 100 important scientists and diplomats from Poland and France. U.S. President Warren Harding had the honor of presenting Marie Sklodowska Curie with a key inscribed with the following words: “From the Women of

Library of Congress

Marie Curie with President Warren Harding at the White House in 1921: "We greet you as foremost among scientists in the age of science."

America" to Madame Marie Curie. The elaborate key was to open a ribbon-draped cabinet, which contained one gram of radium, worth more than $100,000, which was paid for by America's women. His inspiring speech paid great homage to Madam Curie, and expressed profound respect for both her adopted nation, France, and the newly re-created nation of Poland, the land of her birth, which had finally become an independent nation again, after the war:

> On behalf of the American nation, I greet you and welcome you to our country, in which you will everywhere find the most cordial possible reception. We welcome you as an adopted daughter of France, our earliest supporter among the great nations. We greet you as a native-born daughter of Poland; newest, as it is also among nations, and always bound by ties of closest sympathy to our own Republic. In you we see the representative of Poland restored and reinstated to its rightful place, of France valiantly maintained in the high estate which has ever been its right.
>
> We greet you as foremost among scientists in the age of science, as leader among women in the generation which sees woman come tardily into her own. We greet you as an exemplar of liberty's victories in the generation wherein liberty has won her crown of glory. In doing honor to you we testify anew our pride in the ancient friendships which have bound us to both the country of your adoption and that of your nativity.
>
> It has been your fortune, Madam Curie, to accomplish an immortal work for humanity. We bring to you the meed of honor which is due to pre-eminence in science, scholarship, research, and humanitarianism. But with it all we bring something more. We lay at your feet the testimony of that love which all the generations of men have been wont to bestow upon the noble woman, the unselfish wife, the devoted mother. If, indeed, these simpler and commoner relations of life could not keep you from attainments in the realms of science and intellect, it is also true that the zeal, ambition and unswerving purpose of a lofty career could not bar you from splendidly doing all the plain but worthy tasks which fall to every woman's lot.
>
> A number of years ago, a reader of one of your earlier works on radioactive substances noted the observation that there was much divergence of opinion as to whether the energy of radioactive substances is created within those substances themselves, or is gathered to them from outside sources and then diffused from them. The question suggested an answer which is doubtless hopelessly unscientific. I have liked to believe in an analogy between the spiritual and the physical world. I have been very sure that that which I may call the radioactive soul, or spirit, or intellect—call it what you choose—must first gather to itself, from its surroundings, the power that it afterwards radiates in beneficence to those near it. I believe it is the sum of many inspirations, borne in on great souls, which enables them to warm, to scintillate, to radiate, to illumine, and serve those about them.
>
> Let me press the analogy a little further. The world today is appealing to its statesmen, its sociologists, its humanitarians, and its religious leaders for solution of appalling problems. I want to hope that the power and universality of that appeal will inspire strong, devout, consecrated men and women to seek out the solution, and, in the light of their wisdom, to carry it to all mankind. I have faith to believe that precisely that will happen; and in your own career of fine achievement I find heartening justification for my faith.
>
> In testimony of the affection of the American people, of their confidence in your scientific work, and of their earnest wish that your genius and energy may receive all encouragement to carry forward your efforts for the advance of science and conquest of disease, I have been commissioned to present to you this little phial of radium. To you we owe our knowledge and possession of it, and so to you we give it, confident that in your possession it will be the means further to unveil the fascinating secrets of nature, to widen the field of useful knowledge, to alleviate suffering among the children of man. It betokens the affection of one great people to another [*The New York Times,* May 21, 1921].

After President Harding's speech, Madame Marie Sklodowska Curie responded:

> I can not express to you the emotion which fills my heart in this moment. You, the chief of this great Republic of the United States, honor me as no woman has ever been honored in America before. The destiny of a nation whose women can do what your countrywomen do today through you, Mr. President, is sure and safe. It gives me confidence in the destiny of democracy. I accept this rare gift, Mr. President, with the hope that I may make it serve mankind. I thank your countrywomen in the name of France. I thank them in the name of humanity which we all wish so much to make happier. I love you all, my American friends, very much *Science* 1921, p. 497].

The Curies with Missy Meloney (left) in America in 1921. Inset is the front page of Missy's magazine The Delineator, April 1921, where the fund-raising for the gift of radium is publicized on the cover.

THE DELINEATOR

APRIL 1921

THAT MILLIONS SHALL NOT DIE!

CONTENTS

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The trip to the United States was a momentous occasion, not only for Marie Curie, but for the American people themselves. The hospitality and generosity shown to Madam Curie went far beyond a simple fund-raising campaign. In each place she visited, from New York City, to Buffalo, to Chicago, and many other cities, the American people treated her with a respect and dignity usually reserved for heads of state. In some ways, the campaign to raise money to buy Marie Curie a gram of radium, was similar to the great fund-raising campaign in America to build a base for the Statue of Liberty, a gift given by the French nation.

The person responsible for orchestrating this "event," which took Marie all over America to be honored, was an American editor of a popular woman's magazine, *The Delineator.* The woman was a small, dynamic individual named Marie Mattingly Meloney, who wanted everyone to call her "Missy."

Missy had a somewhat unique background. Her father was a doctor, and her mother, his third wife, taught newly freed black slaves in the South. *The Delineator* featured the latest women's fashion, and articles on how to take care of home and family. Missy had tried unsuccessfully, for quite some time, to get a story on Marie Curie, but every time she sent a journalist to Paris, Marie refused to see him. Marie Curie had no use for the media, and had viewed them disdainfully ever since the early days of her discovery of new radioactive elements. Many had tried to penetrate the private life of Marie and Pierre. None had been permitted to speak with her.

In mid-1920, Missy travelled to Paris, determined to speak with Madam Curie herself. Missy was not one to take "no" for an answer, but that was the first answer she got. Undeterred, Missy visited the French author Henri-Pierre Roche (the author of the novel *Jules et Jim*), and asked him to intercede to get Marie to talk to her. Roche was impressed by Missy's genuine enthusiasm, and thought that it would be important for Marie to meet her. Marie agreed to talk to her for a few minutes only, and that encounter led to their lifelong friendship.

When Missy asked Marie what she could do to "help" her, Marie told her that she had no radium to experiment with. After the end of the war, France was depleted of both manpower and money. Although the Radium Institute was built, there was no money forthcoming to equip it properly. The radium which Marie had safe-guarded in Bordeaux during the war was all that France had—1 gram—and that was used, primarily, in the biological section to provide radon tubes for cancer therapy. Marie told Missy that the United States had the world's most plentiful supply, 50 grams.

Missy immediately began to think about what a great good it would be for America to give one of those grams to Marie, and she calculated the cost at about $100,000 per gram (in 1920 dollars). She saw an opportunity before her: Instead of simply getting a "story" for her magazine, she would use her influence, contacts, and clout in a noble cause: The women of America would give Marie Curie a gram of radium. She wanted Marie's plight to generate a response from the American people, and went back to the United States to start the campaign. Initially, however, she thought she might be able to raise $10,000 each from 10 women, but soon discovered that was impossible.

Missy herself became the chairman of the "Marie Curie Radium Fund," and she contacted prominent medical people in New York to ask them to become part of the board. She discovered that she had no problem getting help from American doctors. Marie Curie's name was highly respected among the medical profession in the United States. During the war, Marie had single-handedly educated scores of U.S. physicians at the Radium Institute in X-ray technology, and had enjoyed the Americans' "brash" sense of "we can do anything" that Americans were so famous for at the time.

One of the doctors who immediately joined the board, Robert Abbe, had been experimenting, and using radium therapy for years. He had visited the Curies as early as 1902 in Paris, and had been the first American doctor to use radium in treating cancer and other diseases. Although radiation therapy was still in its infancy, by the year 1920, the year of Missy's visit to Paris, it held out promising hopes to millions of people worldwide.

Other prominent men and women were recruited to sit on the board, including Mrs. John D. Rockefeller, Mrs. Calvin Coolidge, Mrs Robert Mead (the founder of the American Society for the Control of Cancer), and other women with time and money. The advisory committee of scientists included the President of the American Medical Association, and leading representatives from the Rockefeller Foundation, and Harvard, Cornell, and Columbia universities.

Missy used the pages of *The Delineator* as the public solicitor to encourage American women to give what money they had. Young college women took up collections to give to the fund, as did little girls who found out about the campaign, sending in their nickels and dimes. Marie Curie had been receiving letters from all over America for many years from cancer sufferers, who had had their cancer "cured" by enterprising doctors, like Dr. Abbe. One woman, the first to be treated at the hospital in Gettysburg, Pennsylvania, wrote to Marie about her radium treatment: "What it done for me none but God can tell." Madam Curie received letters like this all the time; she was always moved by what people said to her, and she answered the letters when she could.

Perhaps the finest expression of appreciation to Marie Curie, however, was from the American doctors. Those on the board took it as their personal responsibility to ensure that the campaign to raise the $100,000 was more than a success. They wanted not only to buy the gram of radium, but also to ensure that Madam Curie had a modern, well-equipped laboratory. In each city where Marie Curie was to visit, a fund-raising quota-system was set up: New York had a quota of $10,000; Boston and Philadelphia each had a quota of $5,000. Each doctor on the board participated. Dr. Abbe, for example, wrote to Dr. John G. Clark of Philadelphia (both of them were members of the prestigious Philadelphia College of Physicians): "I have by personal appeal to my patients raised over 20,000 dollars myself. . . ."

Dr. Robert Abbe

Abbe was also an avid collector of medical "treasures" belonging to famous medical scientists. At the College of Physicians in Philadelphia, there is a beautiful display in a glass cabinet, in a grand drawing room. It was a gift from Dr. Abbe to the College, and it contains portraits, illustrations, autographed letters, and biographical notes of five medical men, who Dr. Abbe thought had made the most significant contributions to medical science: Benjamin Rush, Edward Jenner, Joseph Lister, Louis Pasteur, and Marie Curie.

Dr. Robert Abbe: U.S. Champion of the Curies

Robert Abbe was born in New York City, April 13, 1851, and died in March 1928. He graduated from the College of City of New York in 1870, and early in his career, he taught drawing and geometry at his alma mater. After graduating with a medical degree in 1874 from the College of Physicians and Surgeons, he became an intern at St. Luke's Hospital in New York.

Abbe was said to be one of the finest surgeons in New York, with an "irreproachable technique," and he became a pioneer in surgical work in gastro-intestinal tract, as well as cerebral, spinal, and plastic surgery. He loved classical art, and it influenced his method of surgery. He was one of the best plastic surgeons in the United States, and did work with severely deformed persons. He also devised "the earliest and possibly the best method of treating impassable strictures of the esophagus."

While he was at New York's Babies & Roosevelt Hospital, Abbe did considerable research on X-rays and corresponded with the Curies. He was a consulting surgeon to other large hospitals, and he wrote numerous scientific papers.

Abbe had six siblings, and one of them, Cleveland Abbe, became the first full-time meteorologist in the United States. While Cleveland Abbe was interested in Oriental archeology, Robert's passion was prehistoric artifacts found at Mount Desert Island, Bar Harbor, Maine, where he had a summer home. Today, there is a museum there with Abbe's collection, which also includes his drawings.

Courtesy of the Philadelphia College of Physicians

Dr. Robert Abbe (1851-1928)

The cabinet showcases the following items, along with a quotation from each individual:

• Rush's gold watch, and his quote: "I make everyone whom I meet contribute to my improvement."

•Jenner's inkstand and a lock of hair, and his quote: "I am not surprised that men are not thankful to me, but I wonder that they are not more grateful to God for the good which He has made me the instrument of conveying to my fellow creatures."

• Lister's case of instruments, and original test tubes used in tests for lactic fermentation, with the words: "The scientist's public life lies in the work that is His."

• Next to Pasteur's hand-made model of a tartrate crystal is his quote: "Opportunity comes to him who is prepared."

• Finally, prominently placed in the center of this exquisite cabinet, is one of the original quartz piezo-electroscope built by Pierre Curie, and used by the Curies in their discovery of new radioactive substances. Alongside it are her simple words: "I desire only to teach."

Dr. Abbe considered Marie's gift the crowning achievement for the display. She wrote him on March 1, 1921:

> It gives me great pleasure to present this quartz piezo-electroscope for such purpose as its historical interest will serve. It was designed by Professor Curie and is one of those used by us in our early research work for measuring the radioactivity of radium. Having served its purpose it was replaced by other apparatus.

When he finally received the long-awaited gift, on April 25, 1921 he wrote: "The dear instrument, my muse says must be quite homesick tonight. But it must know it is among friends. . . . [E]verybody thinks the College of Physicians is in great luck."

Abbe was one of the prime movers behind the fund-raising done by the physicians, and as early as Christmas Day, 1920, he wrote to Dr. Taylor, about Marie's visit to America:

> It is hoped that a considerable sum of money may be given her to purchase radium in this country for her own personal use in further(ing the) study of medicine. . . . I believe America will honor her and give her what she needs."

By April 30, Abbe wrote to a Dr. Taylor: "Our fund is coming on finely. Don't mention it please, but we are up to the 100,000 mark now and going on we ought to have a nice purse for equipment for Madam Curie."

Abbe, who wrote many scientific papers on the use of radium in surgery, always paid homage to the Curies for their discovery. In an article published in the August 15, 1914, *Medical Record,* titled: "Present Estimation of Value of Radium in Surgery," he wrote:

> Into nature's rocks, by the most artful exhibition of scientific detective work, Madam Curie pursued this unknown substance and dragged it forth . . . to reveal the hidden mysteries of physical force and touch human interests in the control of some diseases.
>
> In itself radium illustrates in concentrated form the universal process of change and decay of matter
>
> Its enormous energy is like incorporated life and its electrons like imprisoned life released. . . .
>
> Until we know why cells grow, and what innate power resides in living tissue which compels growth and orderly change in living cells, and until we know why the disorderly and exaggerated overgrowth of the cells forms life-destroying tumors, we will not be likely to know what that influence is, which is shot into the cells by the atoms of radium which reduces them to orderly growth. . . .
>
> Radium is an asset of permanent value to surgery in the treatment of those diseases. . . [cancer]. [T]he real truth [is] that as an agent for the relief of human suffering radium has proved to be a weapon of unique value in the surgeon's hands.

Dr. Abbe was one of the few American doctors who was convinced of the wonders of radium in treating patients, very early after the turn of the century. Some doctors had criticized Abbe's approach, and thought radium much too dangerous to be used. But Abbe was passionately involved in trying new techniques, and new ways to ease human suffering. He was enthralled by the seemingly paradoxical nature of radioactive substances.

In June 1915, Abbe presented an extremely interesting paper, which was read before the 66th annual session of the American Medical Association in San Francisco, and reported in the medical journal *Radium,* involving the "paradox" of beta and gamma rays. He talks about the early pioneers of X-ray technology (known then as Roentgen rays, after their discoverer), who were constantly exposed to gamma rays, which led to the growth of cancerous lesions on their fingers and hands. He had treated many of these cases, and reported in his paper:

> My first case so treated was 1903. Five years after beginning the use of the Roentgen ray, the patient developed a typical epithelioma of the back of the left hand. One application of radium cured it, and there has been no recurrence after 12 years.

After discussing other cases of men who developed cancer and were successfully treated, he reported:

> It seems almost a paradox of radiology that the accepted use of heavy gamma radiation from a Roentgen tube will cause a diseased condition of the skin, which a similar radiation from a tube of radium will cure. This becomes intelligible when we know that the output of the Roentgen-ray tube is almost wholly composed of hard, penetrating, irritating gamma rays. The radium discharges the beta ray in great quantity, as well as the gamma ray. It is the beta ray that has been proved beyond question to be the efficient curative power, and it is only the secondary betas generated by the gamma when striking any resisting substance, that gives it its value in the Roentgen-ray tube work.

Philadelphia College of Physicians

The glass display cabinet donated to the College by Dr. Robert Abbe. Its centerpiece is one of the original quartz piezo-electrometers built by Pierre Curie and used in their research, a gift from Marie Curie.

> Hence, we can understand that surface lesion of morbid cell growth, be it hyperkeratosis or basal cell, is happily cured by the large output of soft radiation of radium. . . .
>
> To sum up, I may say that no cases have presented themselves to me of chronic dermal Roentgen-ray disease in the early stage of thick patches, cracked, ulcerated and painful or of epithelial growths . . . which have not yielded to radium therapy.

Cancer treatment has evolved tremendously since the turn of the 20th Century, from primitive radium therapy—making use of radon (the gas emitted from radium) encased in platinum tubes and applied directly to cancerous tumors. Today medicine uses scores of new radioisotopes, some with half-lives that are only hours long, for diagnosis and treatment, saving countless lives. Dr. Abbe was a bold pioneer in treating cancers, as well as other diseases, with radium and can perhaps be called the father of nuclear medicine.

Madame Curie Captivates America

Marie Curie was the special guest of honor at the College of Physicians on her tour of America, on May 23, 1921, where she was welcomed by Dr. Abbe. It was Marie's wish that he give the speech in her honor, and it was Dr. Abbe who unveiled the priceless gift that she had sent to them. It was the only official "present" that Marie gave to anyone in America. Dr. Abbe's speech referenced all the artifacts in the cabinet, and when he finally got to the quartz piezo-electroscope, his inner muse took over:

> Let us imagine some future evening here in this beautiful hall after the scientific audience has gone, the lights are turned out, the janitor has made his rounds, locked the door, and gone home, the moonlight streaming in the tall windows near the case, the Liberty Bell in Independence Hall has struck midnight by some fairy hand. Then the little fairy spirits that stand guard over these mementos awake. From the Curie instrument one stretches out his hand and touches another of one guarding the Pasteur crystal, grasps it and a chatter in French breaks the silence. This wakes up the sprightly guardian of Lister's instruments and Jenner's inkstand, who join in an international parley at which the American spirit of Dr. Rush climbs out of his invisible retreat and they all dance about and narrate their wonderful past. Then one can see the dawn breaks they all hide again invisible. The janitor unlocks the library and visitors come to study and pay homage to the great names we all worship. This historic instrument will not be lonely. . . .

Abbe ended his speech with a tribute to American women:

> It has been a heart-warming sight to see the universal response of the women of our broad land, poor and rich, contributing as they could to fund to equip Madam Curie's laboratory. The great good that has emanated from them is sure to be now continued.

At the close of his address, Marie Curie rose, put her hand on the quartz piezo-electroscope, and said: "I am glad to present this instrument to so distinguished a society."

Marie Curie's Tour

From the day she landed in New York City, May 11, to her departure in late June, Madame Curie was greeted with flowers, song, and speeches. On May 12, the *New York Times* reported her arrival on page one, with a story headlined "Madam Curie Plans to End All Cancers." This had nothing to do with what Marie Curie said, but was probably the work of Missy Meloney, who wanted to make the greatest impression possible on the consciousness of the American people. Almost as soon as Marie arrived, a well-wisher shook her hand so hard, she had to have it bandaged. Despite the publicity, which she detested, she loved meeting people, and being shown the "best" in America, especially the sacred places of science. The American people loved their scientific "Joan of Arc."

The first gala event for her was at New York's Carnegie Hall, on May 18. It was the largest meeting of American college women that had ever taken place. There were 3,500 representatives of nearly every major woman's college on the Eastern seaboard. The meeting was called to honor Marie Curie, and also was an organizing meeting to launch a movement to bring about disarmament and stop all wars. The event

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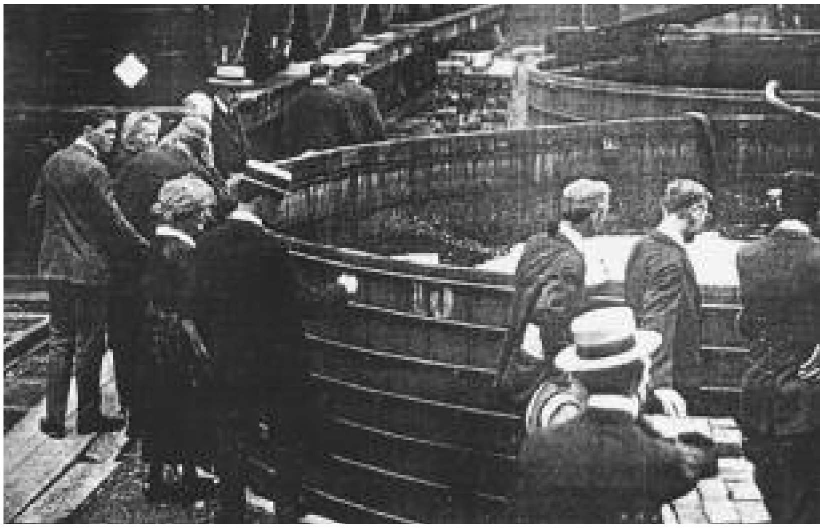
The radium produced for Marie Curie by the Radium Research Laboratory of the Standard Chemical Company in Pittsburgh. The radium looks like table salt, at the bottom of the container. It was presented to Marie in 10 small tubes, contained within a lead-lined steel box inside a mahogany box, that weighed 125 pounds.



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Marie Curie (upper left) studies the process of radium refining at the Pittsburgh plant.

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Chemical preparation of samples to assess their radium content, prior to extraction at the Radium Research Laboratory.

was organized by the American Federation of University Women of the International Federation of University Women. The President of Wellesley College, Ellen Pendleton, presented Marie Curie with the Ellen Richards Memorial Prize, a cash award of $2,000.

The ceremony at Carnegie Hall was unprecedented for its time. As Marie Curie entered the hall, the entire audience stood and applauded for several minutes. The Vassar Glee Club sang an original song written by a member of the faculty, with words composed by a student. She also received a *fleur-de-lys* from representatives of physics and chemistry courses of 15 women's colleges. Madam Curie was moved by the assemblage, and told them: "I thank you from the bottom of my heart for the welcome you have extended to me, and I shall never forget the warmth of your reception."

Just a day earlier, Marie Curie was honored at an event at the American Museum of Natural History. Dr. Michael L. Pupin, Professor of Electrical Mechanics at Columbia University (himself a Serbian immigrant whose first job in America was as a farm laborer) said that "the knowledge of radioactivity which she had helped to reveal was founding a new structure of physics, in which all matter is electricity and each atom a perfect system of electrons." Dr. Robert Abbe was in attendance, and was identified by the *New York Times* in its coverage as "the first surgeon in America to substitute radium treatment for the knife in cancer treatment." Abbe said:

> Today we see a little chance of conquering this last great scourge that has afflicted humanity. . . . That cancer in its milder forms can be cured by radium is indubitable. Humanity demands a cure for the disease in its gravest and most malignant forms, but it will have to wait, for though success is coming, it is coming slowly. Within the next few years I am confident that Madam Curie will be able to reveal something new in this remarkable agent that will help all humanity. In the name of all the sufferers who have been saved and in the name of humanity I thank her for what she has done and is to do.

Also present at the event was Dr. Robert B. Moore, chief chemist of the United States Bureau of Mines, who said:

> The appreciation of science by the women of America will be quadrupled by Madam Curie's visit to us. . . . Thank God we are through with the chemistry of war and back to the chemistry of peace and good will and healing. I bring to Madam Curie, the mother of radium, the love, admiration and affection of the chemists of America.

Other important scientists and doctors present at the event also spoke affectionately of Marie.

The Women's Colleges

Almost as soon as she arrived from France, Marie Curie began a tour of some American universities. In particular, young university women had been very active participants in the fund-raising efforts for the Marie Curie Radium Fund. According to the *College News,* at Bryn Mawr College in Pennsylvania (April 20, 1921), the students' quota for the "gift" from all the universities combined was $41,000, and every female student was asked to give "one dollar."

One of the first colleges Marie visited was Smith College in Northampton, Massachusetts. A young college student at Smith wrote to her mother, the day of the event, May 13, 1921:

> We've done nothing but talk about Madam Curie's visit for a week and we all, of course, went to the ceremonies. They are just over. It was *so* impressive.

The young woman detailed for her mother what everyone wore, where the upper and lower classmen sat, the honor guards, the marching upon the stage, and every detail she could muster:

> Madam Curie and President Neilson came in last and the ceremony and speeches began. . . . The head of the French Department welcomed her in French. Then the head of the Chemistry Department told of her wonderful life work. . . .

The student continued in this vein, describing the singing of the Alma Mater, the faculty procession:

> We all formed a double line of girls from the "Libe" [library] clear across campus to the Hall and serenaded her en route. She was very sweet looking but she looked tired and pale. . . . She is extremely shy and modest.

It was no wonder that Madam Curie was so tired, for after these ceremonies, she departed immediately for Vassar College and West Point. Marie Curie had never fully recovered from her very exhaustive five years on the battlefield of France. Years before that, she had labored unceasingly in the discovery of radium, the development of radium metal, and the work on polonium, running the Radium Institute, and coordinating work with Dr. Regnaud of the Institute's biological section. Her trip to America was not a vacation, and definitely wore her down. Nevertheless, she made herself available at every opportunity because she understood the positive impact her presence had on the millions of American women who made her their idol, especially the women studying at universities.

Madam Curie spoke little at most of these ceremonies. That is why it is particularly interesting that she gave a modest speech at Vassar College the next day, her only one at an American college. Her address is titled "The Discovery of Radium" and is a short, eloquent story of her early work with Pierre Curie, and how she developed the idea that other radioactive elements existed, and how they discovered them. A copy of the address can be purchased from Vassar, which has Marie Curie's writing on the cover, with these words:

> It is my earnest desire that some of you should carry on this scientific work and will keep for your ambition the determination to make a permanent contribution to science. . . .

Other universities and colleges were privileged to have Madam Curie as their special guest, and many conferred honors upon her at their convocations. Women's Medical College in Philadelphia received a visit May 23; also that day, she received the honorary degree of Doctor of Law and Philosophy at the University of Pennsylvania. She spent a few days at Bryn Mawr College, as a guest at the home of the dean, and on May 25, she visited Pittsburgh, and received the degree of Doctor of Law. On June 1, she received the Doctor of Science degree from Columbia University

In Madame Curie's *Autobiographical Notes,* she talks about the universities for women in America:

> My short visit could not permit me to give an authorized opinion on the intellectual training, but even in such a visit as I made, one may notice important differences between the French and American conception of girls' education, and some of these differences would not be in favor in our country. Two points have particularly drawn my attention: the care of the health and the physical development of the students, and the very independent organization of their life which allows a large degree of individual initiative. . . .
>
> The colleges are excellent in their construction and organization. They are composed of several buildings, often scattered in very large grounds between lawns and trees. Smith is on the shore of a charming river. The equipment is comfortable and hygienic, of extreme cleanliness, with bathrooms, showers, distribution of cold and hot water. The students have cheerful private rooms and common gathering rooms. A very complete organization of games and sports exists in every college. The students play tennis and baseball; they have gymnasium, canoeing, swimming and horseback riding. Their health is under the constant care of medical advisers. It seems to be a frequent opinion of American mothers that the existing atmosphere of cities like New York is not favorable to the education of young girls, and that a life in the country where the open air gives more suitable conditions for the health and tranquility of studying.
>
> In every college the young girls form an association and elect a committee which has to establish the internal rules of the college. The students display a great activity: they take part in educational work; they publish a paper; they are devoted to songs and music; they write plays, and act them in college and out of it. These plays have interested me very much in their subjects and the execution. The students are also of different social conditions. Many of them are of wealthy families, but many others live on scholarships. The whole organization may be considered as democratic. A few students are foreigners, and we have met some French students very well pleased with the college life and studies.

Every college takes four years of study with examinations from time to time. Some students afterwards do personal work, and acquire the degree of Doctor which does not exactly correspond to the same title in France. The colleges have laboratories with many good facilities for experimentation.

I have been strongly impressed by the joy of life animating these young girls and expanding on every occasion, like that of my visit. If the ceremonies of the reception were performed in a nearly military order, a spontaneity of youth and happiness expressed itself in the songs of greeting composed by the students, in the smiling and excited faces, and in the rushing over the lawns to greet me at my arrival. This was indeed a charming impression which I could not forget [Curie 1923, pp. 230-232].

Marie Curie spent some time in Pittsburgh, as she was very keen to visit the Standard Chemical Company, which was where radium was manufactured in America. She loved her time in Pittsburgh, and enjoyed talking to the scientists and engineers about radium production. However, the greatest part of her trip was yet to come. The United States had become the world's largest manufacturer of radium in the world, and she was to visit the mines and manufacturing places of the American West.

The Grand Canyon: Mining the Precious Ore for Radium

Several weeks later, she visited Colorado, the Grand Canyon, and the mining areas in the region, where radium was extracted from carnotite, a uranium ore. Carnotite is a mineral, usually bright yellow in color, which had attracted the attention of early settlers. The Ute and Navajo Indians are said to have used it for yellow pigments. *Radium* magazine, in 1913, described it as follows:

Pure carnotite mineral contains from 20% to 54% UO_3, from 7% to 18% vanadium pentoxyde, 5% to 6.5% K_2O, 0.3 to 2.8% barium oxide, 1.6% to 3.3% calcium oxide, small quantities of lead, and traces of aluminia, iron, arsenic, and phosphorous. The mineral powder is always mixed with more or less quartz and sand, and the intensity of the yellowish color of this mixture permits the prospector to get quickly a rough estimate of the richness of the material. Very rich mixtures of carnotite with sand stone does not contain more than 1.5% to 6% U_30_8. Such carnotite sand stones were found on accurate analysis to contain from 3.5 to 15 milligrams of radium [metal] per ton.

Madame Curie especially enjoyed her trip to the Grand Canyon. It served as a respite to her frantic schedule, and gave her time to relax. She and her daughters rode ponies and mules, up and down the hills where the ore was mined. She was happy to note that the miners were using the exact method of treating the ore, which she and Pierre had invented. Carnotite is not as rich in radium as is pitchblende, and extracting the radium was a huge enterprise. After the Curies had discovered radium and polonium, the Austrian government promptly made a monopoly out of the large deposits of pitchblende that existed, although every bit of radium produced was sold for science, at a loss. The first production of radium in America was at the Carnotite Chemical Reduction Plant in West Seneca (in today's Lackawanna) outside of Buffalo, New York. The plant operated from 1902 to 1908

A Buffalo attorney, Stephen Lockwood, with the assistance of a Washington, D.C., millionaire, Thomas F. Walsh, were the first to attempt to produce high-grade radium. They fought, unsuccessfully, to create a U.S. Government Bureau of Mines. It was their stated desire to keep the cost of radium down. Mr. Lockwood had carried on correspondence with Pierre Curie in the very early 1900s, sending him samples of their product, which were often weak, and Pierre would advise him of how best to go about production.

Eve Curie refers to Stephen Lockwood, in her biography of her mother, in the section of her book about why her parents decided not to apply for patents. She quotes her father: "No, it would be contrary to the scientific spirit. . . . I shall write tonight, then, to the American engineers, and give them the information they ask for. . . ." This is a reference to Stephen Lockwood. Years later, when Eve was writing her mother's biography, Lockwood sent her a beautiful manuscript, as a souvenir, which contained Lockwood's account of the development of the young radium industry in Buffalo, and also the letters that Pierre Curie had written to him.

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The Colorado carnotite ore contained only 1 gram of radium in every 500 to 600 tons. The ore was reduced down to 125 tons, and then shipped to the Pittsburgh Radium Research Laboratory. Shown here is the crystallization room, where the radium is recovered by fractional crystallization—the same method used by Marie Curie in her original experiments.

After the Buffalo enterprise failed, a new radium industry was built in Pittsburgh in 1911, by Joseph M. Flannery. Flannery had made millions with his vanadium mining operation in Peru, and he poured most of the profits into radium. It was Flannery who discovered the merits of vanadium as an alloy for steel. Flannery built the Standard Chemical Company, headquartered in Pittsburgh, together with the extensive mining operation of carnotite in the wilderness of Colorado. The radium discovered by the Curies had been worked from 5 to 6 tons of pitchblende, and to extract radium from carnotite was even more arduous a task:

> In the Colorado ores there is only 1 gram of radium in every 500 or 600 tons of [carnotite] ore, and even to obtain each of these 500 or 600 tons it is frequently necessary to handle 100 tons of worthless material. . . . Burros were used to carry the ores from the deposits in the mountains to this mill, and to carry back to the miners water and other supplies. . . [*Bulletin of the Pan American Union* 1921, p. 38].

When Madame Curie and her daughters went to Colorado, this is what they saw:

> . . . [P]rospecting is done by drilling in what seem likely spots with jack hammers and with diamond drills . . . portable gasoline compressors were used as the source of energy. In this uninhabited area of southwestern Colorado, and southwestern Utah, pockets of carnotite were discovered from a few pounds of ore, to, in exceptional cases, 1,800 tons. Once the ore is mined, it is taken to a concentration mill nearby, where 500 tons is reduced to 125 tons. It is now in a powdered form, and shipped in 100 pound sacks, by wagon, and, where possible, by motor trucks, the 65 miles to Placerville, Colorado. Here a narrow-gauge railroad takes it to the transcontinental railroad at Salida, Colorado. From Salida it travels the 2,300 miles to Canonsburg, Pa., just outside Pittsburgh. . . [*Bulletin of the Pan American Union* 1921].

The mill in Colorado and the operation leading up to it, employed 300 men. In Canonsburg, which Madame Curie had visited earlier in her trip, the pure radium salts were produced: 1 part radium to 100,000,000 parts ore! There, on a massive scale, Madame Curie saw the exact procedure she and Pierre had devised 23 years earlier. Only here, the most modern technology of the day was at hand, and the quantities were much larger: The plant used 10,000 tons of distilled water, 1,000 tons of coal, and 500 tons of chemicals. Any vanadium and uranium that remained from this process was also saved for use.

The radium which Madame Curie received as a gift from the women of America came from this source. At that time, the going price for a gram of radium was $120,000, which was reduced by the industry to $100,000 in her honor. In 1921, the world supply of radium was said to be about 140 grams, and the Standard Chemical Company in the United States had produced 72.5 grams of this highly radioactive and precious resource. Nearly all of the world's radium was used in medical research, mostly in cancer. The fact that 1 gram was given to Madame Curie, through the contributions of American woman, and the American physicians who spurred the fundraising, is a tribute to our nation. France had given America Lafayette and the Statue of Liberty, and we were able to reply in kind with this noble gift.

After her Grand Canyon stay, Madame Curie travelled to Chicago, where two more honorary degrees awaited her. Chicago was the home of Dr. and Mrs. Vernon Kellogg, who were instrumental in helping Missy Meloney to bring Madame Curie to America. When they visited Paris, they were welcome guests at the Curie home. It was Missy and the Kelloggs who persuaded Madame Curie to write the beautiful biography of Pierre Curie, to which she appended her *Autobiographical Notes*. The Kelloggs also translated the book from French, and helped with corrections.

Madame Curie received honorary degrees from the University of Chicago and Northwestern University, where Dr. Charles Horace Mayo, co-founder of the Mayo Clinic, was also honored with a degree. In her *Autobiographical Notes*, Madame Curie mentions that she gave a lecture on the "Discovery of Radium" to the American Chemical Society in Chicago. Unfortunately, there is nothing written about this by the Society.

An amusing incident took place during her visit to Chicago. She was invited to swim in the new gymnasium pool at Northwestern, but refused, and she insisted instead that she wanted to be rowed out quite a distance into Lake Michigan to swim. Her host and hostess at the university were extremely nervous about this request, but they complied. The *Evanston News-Index*, headlined a page one story June 17, 1921, "Mme. Curie Likes It Over Her Head." The newspaper reported that her hosts

> nervously clasped and unclasped their hands. Meanwhile Mme. Curie stood up in the boat, and dived off. She swam about with evident joy and the hurry-up call for lifesavers was not sent in. She stayed in for about 20 minutes and was delighted. . . .

From Chicago, the Curies travelled by train to Buffalo, N.Y., and there to greet them were a group of prominent American-Polish academicians at the train station, who were mightily disappointed when the Curies decided to stop in Niagara Falls and see the sights there first. Madame Curie did, however, make a visit to the Gratwick Cancer laboratory in Buffalo (today it is greatly expanded and known as Roswell Park, located near downtown Buffalo). She was also honored in Niagara Falls by university women from Toronto, Canada, but she felt so ill that she could not attend the luncheon. She was made an honorary member of the Buffalo Society of Natural Sciences, but, again, she was too ill to attend the festivities. Madame Curie grew increasingly sick from her long and taxing journey, and stayed only two days in Buffalo, resting for most of that time.

The next stop for the Curies was Wellesley College in Massachusetts, followed by a trip to Boston. Although nearly every university that hosted Madame Curie had conferred

Marie Curie and Einstein

One of Marie Curie's greatest admirers among her scientific colleagues was Albert Einstein. In the early days, before Einstein's immense popularity, it was Madame Curie and Raymond Poincaré who were true friends and advocates of the young physicist. In the early 1950s, long after Madame Curie's death, Einstein was asked, in an interview, which physicist he respected the most. Einstein named two: Hendrik Lorentz and Marie Sklodowska Curie. Of Curie he said:

> I have always admired . . . Marie Curie. Not only did she do outstanding work in her lifetime and not only did she help humanity greatly by her work, but she invested all of her work with the highest moral quality. All of this she accomplished with great strength, objectivity, and judgment. It is very rare to find all of these qualities in one individual. In fact, if more European intellectuals had had Madame Curie's modesty, conditions might have been brighter [*Polish Review,* p. 131]

Radiological History and Heritage Charitable Trust

Marie Curie with Albert Einstein in Geneva, 1925.

Both Curie and Poincaré gave outstanding references to Einstein when he offered to teach at the University of Prague. Marie wrote:

> I much admire the work which M. Einstein has published on matters concerning modern theoretical physics. I think moreover, that mathematical physics are at one in considering his work as being in the first rank. At Brussels, where I took part in a scientific conference attended by M. Einstein, I was able to appreciate the clearness of his mind, the shrewdness with which he marshaled his facts, and the depth of his knowledge. If one takes into consideration the fact that M. Einstein is still very young, one is justified in basing great hopes on him and in seeing in him one of the leading theoreticians of the future. I think that a scientific institution which gave M. Einstein the means of work which he wants, by appointing him to a chair in the condition he merits, could only be greatly honored by such a decision and would certainly render a great service to science [Clark 1971, p. 149].

When Einstein and his wife, Mileva, went to Paris, in March 1913, they stayed with Madame Curie. A delightful trip to Zurich by the Curies, where they spent the holiday with the Einsteins hiking through the mountains on foot, was fondly remembered by one of Einstein's sons. He recalled how Marie would demand that his father name every peak on the horizon. They had discussions on the new discoveries in radioactivity, and Einstein would postulate his ideas on subnuclear particles, and their relativistic speeds. Eve Curie remembered that her mother was one of the few people in all of Europe, "with her exceptional mathematical culture," who could talk to Einstein about his ideas. (As a youngster, one of Marie's intellectual heroes, she notes, had been Carl Gauss.)

On June 24, 1922, Einstein's good friend, German Prime Minister Rathenau, was assassinated, and a wave of anti-Semitism began to sweep Germany. At this time, Einstein was a member of the International Committee on Intellectual Co-operation, along with Madame Curie. The Committee had been formed out of the ashes of World War I, as part of the League of Nations. Curie thought this was an important scientific body, and her interest was in the area of scientific education. Several weeks after Rathenau's death, Einstein wrote to Curie to explain that he was resigning: "not only because of the tragic death of Rathenau, but because on other occasions I have observed a strong feeling of anti-Semitism among the people whom I am supposed to represent; as they seem on the whole to lean that way, I feel that I am no longer the right person for the job."

Madame Curie wrote back to him, urging him to stay on, and insisting that this is what Rathenau would have wanted him to do. The situation for scientists in Germany was not good, however, and the Treaty of Versailles, among other things, had hurt the good will toward scientists there. First, no German scientist was allowed to go to the Solvay Conference in 1922, except for Einstein; second, he was the only German scientist invited to be on the Committee at the League of Nations. This disgusting set of circumstances, put Einstein in a vise. Nonetheless, Marie pushed him:

> I have received your letter, which has caused me a great disappointment. It seems to me that the reason you give for your abstention is not convincing. It is precisely because dangerous and prejudicial currents of opinion do exist that it is necessary to fight them, and you are able to exercise, to this extent, an excellent influence, if only by your personal reputation which enables you to fight for toleration. I think that your friend, Rathenau, whom I judge to have been an honest man, would have encouraged you to make at least an effort at peaceful, intellectual international collaboration. Surely you can change your mind. Your friends here have kind memories of you [Clark 1971, pp. 354-355].

Einstein responded to her that he was convinced that the League of Nations, not the Committee on Intellectual Cooperation, "was a pliant tool of power politics under the cover of objectivity. . . ." He and Curie remained firm friends, despite their differences, and later, Einstein relented and did rejoin the Committee.

Madame Curie and Paul Langevin were responsible for the invitation to Einstein to lecture at the Sorbonne in 1922, which he accepted. The animosity between France and Germany after the war was so deep that many members of the French Physical Society threatened to protest the event. Einstein had to "be secreted from the French-German border into Paris by Langevin," and although the event was a rousing success, "nationalist papers" on both sides attacked the event (*Polish Review,* p. 136).

After Madame Curie died in July 1934, a Memorial Celebration of her life was held in New York City, on January 23, 1935. Present were the Ambassador of Poland Stanislaw Patek, the Consul General of France and Poland, and Mayor LaGuardia of New York. Albert Einstein eulogized his colleague and friend, in a beautiful statement (found in the Meloney Collection at Columbia University Library):

> When an outstanding person such as Madame Curie has completed her life's course, we should remember what she gave as the fruit of her work to humanity, because the ethical qualities of leading personalities of a generation are of greater importance for that generation and for posterity than the purely intellectual accomplishments. And these latter are, to a higher degree, dependent, more than one usually thinks, on the greatness of character.
>
> I had the good fortune to be connected with Madame Curie through a beautiful and unclouded friendship of 20 years, during which I learned to know and admire her human greatness, in an ever-increasing degree. She had a strong and definite will, possessing a sternness towards herself, with an objectivity which made it impossible for any prejudice to influence her decision. These qualities are seldom combined in a human being. At all times she was aware of being a servant to humanity, her deep modesty never allowing her to be self-satisfied. She was ever alive to the harshness and injustice of society, towards which she expressed herself through an outward coldness which might have been easily misunderstood by outsiders, and that specific sternness was not to be softened through any pretense. When she knew the path to be right, she would follow it without compromise and with the utmost determination.
>
> The greatest scientific achievements of her life, the proof of the existence and the isolation of radioactive elements, was due not only to a daring intuition, but also to a devotion and determination in the accomplishment under the most unheard of difficulties which have seldom been encountered in the history of experimental science.
>
> If only a small part of Madame Curie's greatness of character and devotion would be alive in the intellectual circles of Europe today, the destiny of Europe would be a better one.

upon her an honorary degree, Harvard had flatly refused to do so. Missy Meloney wrote to Harvard's President Emeritus, Dr. Charles Eliot, pleading with him to honor her. On December 18, 1920, Eliot wrote a note to Missy saying that he thought it was a fine idea, but that Dr. William Duane, who had worked with Madame Curie at the Radium Institute in Paris, and other members of the faculty, were opposed. According to Eliot, Dr. Duane reportedly said: ". . . credit does not entirely belong to her. . ." for the discovery of radium, and that since Pierre's death in 1906 ". . .she has done nothing of importance. . . ."

Missy was aghast. Whatever Dr. Duane did or did not say, there is no evidence that Marie cared at all. From all indications, Madame Curie truly liked Dr. Duane, and was anxious to see him and visit the laboratories at Harvard and at the Boston hospitals. Dr. Duane hosted the Curies while they were in Boston.

Harvard joined with Radcliffe, Wellesley, Simmons, and other New England colleges in welcoming Madame Curie to Boston, with a grand reception at the Sanders Theater. President Lowell of Harvard escorted her in, and Marie was greeted "with deafening applause by the 900 persons assembled there," according to the *Boston Globe*, June 21, 1921. The *Globe* reported that "The French tricolor draped with the American flag and the banner of Harvard was significant of the union of all countries and peoples in admiration of her greatness."

President Lowell said, "The discovery of Mme. Curie gave the world new ideas concerning the structure of the universe and opened a new path of thought to the scientists." Lowell then compared her to Isaac Newton. Prof. Richards of Harvard's Chemistry Department gave a speech, and a chorus of Polish children sang for her in the balcony above the stage. The Curies visited the Cruft Laboratory in Cambridge and also the Jefferson Laboratory.

Madame Curie, her two daughters, and Missy Meloney then departed for New Haven, their last stop before departing for France. There Madame Curie received a Doctorate of Science from Yale University. Again, there was a huge dispute at the university as to whether or not to confer on her the honor, and what happened was interesting. The chief of radiochemistry at Yale, Dr. Bertram Boltwood, along with most of the other academics in chemistry and physics, were against the honor. However, the medical doctors at Yale had their way, and the honor was bestowed.

Later, in 1925, John Johnston, head of the Chemistry Department at Yale, wrote to Robert M. Hutchins, Secretary of Yale, and said that there was no reason to invite Irène Curie to come to Yale (Irène had expressed the desire to do some research at Yale, as she thought it was one of the best equipped laboratories in the United States). Johnston wrote, " . . .moreover, had her name not been Curie, we should have heard little of her. . . ." Despite his prejudices, Irène and Frédéric Joliot-Curie were to win the Nobel prize in physics, 10 years later!

Madame Curie and her two daughters left New York on June 25, 1921, with their radium, mesothorium, and several tens of thousands of dollars that had been raised to help finance the Radium Institute. She had avoided the press the entire time she was in America, though the press certainly had not avoided talking about her while she was there. The day before she departed, she gave a special interview to *Scientific American,* printed on July 9, 1921, headlined "A Chat with Madame Curie: What the Discoverer of Radium Thinks of Us and What We Think of Her," by Austin C. Lescarboura. The article discusses her thoughts about American universities:

> But the greatest of all, in Madame Curie's opinion, are our free institutions of learning, especially in such centers as New York City, where the lack of financial means need not necessarily stand in the way of the ambitious boy or girl desiring an academic training.

She was also asked what she thought of America's scientific laboratories, and whether Americans were too obsessed with "dollar-chasing habits."

> Here is the answer: startling, to be sure, but nevertheless true. Madame Curie believes that much of the work done in our leading laboratories and universities is done for the sake of science—pure science—and does not contain the slightest trace of industrial motives. Our government laboratories are doing wonderful work in many different directions for the good of science and humanity at large, and with the dollar sign conspicuous by its very absence. Truly, we are not the money grabbers or dollar chasers that we have been made out to be by others as well as in our own minds.
>
> Still, there is something wonderful about our industrial prowess. Madame Curie was delighted with our development of the radium industry; indeed, we have made an industry of it. . . .
>
> Despite 20 years of study and research devoted to radium and radioactivity, Madame Curie admits that she has much to learn. . . . Radium, she tells us, must be handled with great care. Careless or inexperienced handling may prove dangerous and perhaps fatal. We noted that one of her hands had been affected by the radioactive rays and her general health. . . .

Asked what she will do with the gram of radium, Marie describes the Curie Institute in Paris, and its division of labor between physicochemical and physicobiological, and said that the radium would be used in both divisions. She also mentioned that she was looking forward to a lengthy rest during the summer, with a return to work in September with radium and mesothorium. The magazine then informed its readers that "special precautions" had to be taken on the ship, to make sure that the instruments (compasses, and so on) were not affected by the radioactive cargo.

Another excellent article appeared in *Current Opinion,* on June 21, titled, "Madame Curie on the Healing Method of Radium" In that article, there are one and a half pages of quotations from her on her work against cancer, making it clear why she was so happy to have mesothorium. She was planning to use thorium X in experiments for treating cancer. This isotope, which has a very short half-life, is prepared using mesothorium.

The American Gift

Madame Curie was extremely grateful to the American population for its support of her work. As early as 1907, Andrew Carnegie gave her a series of annual scholarships, which enabled students from around the world to study with her. Over the years, Carnegie donated tens of thousands of dollars for this.

Five years after her visit to the United States, Marie wrote a paper called "The American Gift," published with an introduction by Dr. Francis Carter Wood, of the Crocker Memorial Cancer Research Laboratory at Columbia University, in which she describes the work done at the Radium Institute, in both the biological and physicochemical sections, and tells what kind of work she has been doing with that radium:

> My own experiments with the American radium have been mostly devoted to research on radioactive transformation. It is a well known fact that scientists have not been able till now to alter the course of these transformations by any means at their disposal, and this leaves us utterly in the dark as to the possible reasons of the transformation. We know that atoms of radium break up from time to time, producing spontaneous radiation, while atoms of lead, gold, or other metals do not show radioactivity, but why it is so, we could not tell. . . . If this could be done, the experiment would throw light on the cause of the atomic change and on the atomic structure. . . [Meloney Collection].

She describes other theories and experiments done by other physicists, and then talks about her experiments with polonium:

> Thus, in several series of experiments with polonium exposed to the radiation of radium, I noticed a small increase of the rate of transformation of polonium; however the whole evidence made me think that the effect was not to be looked on as a true change in the average life of polonium atoms, but rather as a decrease of intensity related to a slight superficial alteration in the disposition of the radioactive material. Neither in this case nor in other cases could I make sure of a change in the rate of transformation, even to the extent of one in [a] thousand.
>
> I am also pleased to mention the interesting experiments performed by Dr. Welo, an American scientist, who worked some time in my laboratory and tried by a sensitive method [to discover] if the absorption of γ [gamma] rays could be provided by the American radium tubes. No effect, however, was observed. The work had been undertaken as a possible test for some theoretical views on the shape of the electron.
>
> It is my wish to express to the Committee of the Marie Curie Radium Fund and to the President of the Committee, Mrs. W.B. Meloney, my high appreciation of the friendly gift. It is dear to me not only because it

brought a very important increase of working means for my Institute; but even more so as a symbol of the sympathy of a great nation for a scientific ideal. A beautiful example has thus been given and a step has been made to the nearer understanding of this ideal by all citizens. Pasteur has said that "Laboratories are sacred places, temples of the future, where humanity grows, fortifies itself and becomes better," that they ought to be multiplied and ornamented, because in them is our hope of welfare by peace and civilization. Surely that feeling inspired my friends in [the] United States who wanted to give me support in my activity. . . .

A Second Gram of Radium: 1929

During the 1920s, Madame Curie's work involved running the Radium Institute in Paris, and she was also responsible, along with her sister, Bronya, for building the Radium Institute in Warsaw, Poland. The financial situation in Poland after World War I, was even more disastrous than it was in France, as Poland had only just become a nation for the first time in more than a hundred years. To build the Institute in Warsaw, the Polish population was appealed to in the most direct fashion. Subscriptions to buy a "brick" for the building were taken by every person, as Poland's most famous citizen called on the population to create the new institute. The greater problem, however, was to secure the radium. Marie had used some of the money she received from her first trip to America, to "rent" radium for the scientists in Warsaw.

Once again, in 1928, Marie appealed to her good friend, Missy Meloney, telling her plainly that she needed another gram for the Polish Radium Institute, and asking whether something could be done from the good-hearted people of America. By this time, Missy was no longer with the woman's magazine *The Delineator,* but had become the editor of the *Sunday Magazine* of the *New York Herald Tribune*. Marie also had plans to bring Bronya to America for her next trip to America.

Missy, who could be counted on to do anything for her dear friend, began to organize the second Curie trip to America. Missy told Marie: "I no longer find many things in life worthwhile, but to serve in even this menial way in a great cause is a real compensation for me" (Reid 1974, p. 291). However, Missy had to explain that there were some problems with this second campaign. The American population had become politically "small-minded," and had become, through their own fault, "isolationists" and backward. Missy begged Marie not to bring Bronya to America, because she was afraid that the American people would not be as magnanimous as they had been in 1921, and, therefore, would not respond to helping Poland. She had already arranged for Marie to be an "official" guest of the White House, with an invitation from the newly elected Herbert Hoover, whom Missy thought was magnificent. Missy was a staunch Republican, and wrote many letters to Marie about Hoover saying that he was a "scientist and a humanitarian" and not "a politician," and that he was on the Marie Curie Radium Fund Committee of 1921 (Reid 1974, p. 292).

Hoover, a much maligned President, was an engineer, had met Curie on her first trip to America. His invitation to stay at the White House was a "first," as no foreigner had ever been given such a privilege. Hoover's Achilles' heel was his stupidity on the issue of economics, and his reluctance to do what was necessary to end the depression, which his successor, Franklin Delano Roosevelt, was able to do. While Madame Curie was in America in 1929, one of the events that she attended was the 50th anniversary celebration of Thomas Edison's invention of the electric "lamp," an event attended by scientific and political dignitaries from all over the world. Hoover gave a tribute to Edison, in which he also specifically attacked Malthusian ideology:

> It is the increasing productivity of men's labor through the tools given us by science that shattered the gloomy prophecies of Malthus. More than a century ago that great student held that increasing population would outrun the food supply and starvation was to be the inevitable executioner of the overcrowded earth. But since his day we have seen the paradox of the growth of population far beyond anything of which he ever dreamed, coupled at the same time with constantly increasing standards of living and ever-increasing surplus of food. Malthus was right except for a new contestant in the race with his principle: That was more scientific research, more discovery. And that race is still on. If we would have our country improve its standard of living and at the same time accommodate itself to increasing population, we must maintain on an even more liberal scale than ever before our great laboratories of both pure and applied science. Our scientists and inventors are amongst our most priceless national possessions. . . [*Science* 1929, p. 412].

Unfortunately, the American population was not so enlightened. So while Marie did return to America, Bronya made the decision not to go, thinking that her presence might detract attention from the radium mission. At the same time, in order to keep the cost of the radium down, nations were allowed to enter bids, and Belgium won with the asking price of $50,000 per gram, which enabled the Marie Curie Radium Fund Committee to raise the funds. In fact, when Marie arrived on October 15, 1929, the *New York Times*'s article, titled "Mme. Curie Arrives, Happy to Be Back," makes no mention of Poland, until the very end of the article, reporting, "This gram of radium Mme. Curie will donate to the Radium Institute under construction at Warsaw." In other press coverage of her trip, Poland is either not mentioned, or is referred to in this fashion.

Marie's health had not improved since her last visit, and she had a great difficulties with her sight, so Marie visited only one college, and kept her visit short.

Her only public appearance, in New York, was on Oct. 31, as the guest of honor before the American Society for the Control of Cancer (later called the American Cancer Society), which was headed up by Mrs. Robert Mead, a prominent woman in New York and one of the driving forces for the Marie Curie Radium Fund. Her remarks were broadcast on the radio.

Cancer was considered to be such a scourge that in

1927, U.S. Senator Matthew M. Neely of West Virginia, made a public offer to reward $5 million to anyone who could cure it. At this time in history, cancer research was privately funded. It wasn't until August 5, 1937, when Franklin Delano Roosevelt signed into law the creation of the National Cancer Institute, that the fight against cancer received federal funding. The Institute was a division of the U.S. Public Health Service, and had to report to the Surgeon General.

Madame Curie was particularly excited by her visit to General Electric in Schenectady on Oct. 23. In honor of her visit, General Electric had closed the plant and put everything at her disposal; the only previous time this had been done was when Charles Lindbergh visited the plant. Her guide was Dr. W.D. Coolidge, the inventor of the Coolidge X-ray tube. Madame Curie was invited to carry out any experiment that she wished, and to use any apparatus that interested her, with the assistance of any scientist at the plant.

On October 25 and 26, she was the guest of St. Lawrence University in Canton, New York. The University had constructed the Hepburn Science Building, named after philanthropist A. Barton Hepburn, who had given $300,000 to build it, and Madame Curie had been invited to dedicate the building in 1926. At the time, she could not attend, so the University had waited for the dedication until she arrived, three years later. On the doorway of the Hepburn Hall of Chemistry is a bas-relief of Madame Curie and Owen D. Young, of the General Electric Corporation, a graduate of St. Lawrence, who hosted Madame Curie on her 1929 tour.

St. Lawrence University

The Hepburn Science Building, at St. Lawrence University, which Madame Curie dedicated on her 1929 trip to America. At the doorway is a bas-relief of Marie Curie (at right). Inset is a photo of Curie with Owen Young of General Electric, a St. Lawrence graduate who hosted her on this visit.

At the dedication ceremony, Madame Curie said:

> I dedicate this laboratory to scientific research in the field of chemistry. It is a pleasure as well as an honor for me to have been asked to come to St. Lawrence University on this occasion. I appreciate highly this new important development of the University, and fully realize the need of it at a time when physics and chemistry are in constant and amazingly rapid progress. It gives confidence in the future of your University to know that as soon as the need had been made clear the new laboratory was erected by the devotion of those who have been educated here. I am in sympathy with the feeling that having received high education one should have the desire to extend the same privilege to others. I also believe that pure scientific research is the true source of progress and civilization and that by creation of new centers the number of men and women who are able to devote themselves to science shall be increased. For all these reasons I congratulate St. Lawrence University. . . .

After this ceremony, Madame Curie was asked to plant a beautiful symmetrical evergreen to the west of the building, "to become a living momento of her visit to St. Lawrence." She was handed a small souvenir-size shovel, which was supposed to be used to dig a symbolic shovel of dirt. However, Madame Curie put the small shovel aside, picked up a real shovel, and began digging the hole herself. Everyone was surprised by her enthusiasm. "I do this very willingly, and hope that your University will grow as the tree," she said.

Also, on the occasion of her visit, the oldest member of the faculty, Dr. Charles Kelsey Gaines, from the class of 1876, composed the following sonnet, which he read to her, after she received an honorary Doctor of Science degree:

To Madame Curie

What age-long effort had essayed in vain
This woman wrought. She loosed the Gordian knot
That held the conquest of the world, and what
The frustrate alchemist could ne'er attain
She has achieved. She broke the primal chain
That binds the elements; she touched the spot
Where lies the hidden spring," and lo! The plot
And secret of the universe lay plain.
Yet what the alchemist in vain had sought
For greed and dazzled by the lure of gold,
She only that she might the truth unfold,
Still toiling for the love of man, has wrought.
Let all the ghosts of alchemy bow down,
While on this woman's brow we set the crown.

On October 30, 1929, Madame Curie was presented with a check for $50,000 from President Herbert Hoover in the building of the National Academy of Sciences and National Research Council. Less than a week earlier, Black Thursday had hit America, thrusting the nation into years of economic chaos. President Hoover, however, paid the following tribute to Madame Curie:

I am sure that I represent the whole American people when I express our gratification to Madame Curie that she should have honored our country by coming here. We give to her the welcome of a people who are grateful for the beneficent service she has given to all mankind.

It is not necessary for me to recount the great fundamental discovery associated with the names of her late husband and herself. The discovery of radium was an outstanding triumph of research in the realm of pure science. It was indeed a great and successful exploration into the unknown from which a new truth has brought to the world a practical revolution in our conceptions of substance. It has advanced all thought on the constitution of matter. And like all great discoveries of fundamental substance and fact it has found application to human use. In the treatment of disease, especially of cancer, it has brought relief of human suffering to hundreds of thousands of men and women.

As an indication of the appreciation and the respect which our people feel for Madame Curie, generous-minded men and women under the leadership of Mrs. William B. Meloney have provided the funds with which a gram of radium is to be purchased and presented to the hospital and research institute which bears her name in Warsaw. The construction of this hospital was a magnificent tribute by the city of her birth and the Polish people, in which the American people are glad to have even this opportunity of modest participation. The whole of this occasion where we pay tribute to a great scientist is again a recognition of the fundamental importance of scientific research and a mark of public appreciation of those who have given their lives to human service through its profession.

Madame Curie, upon accepting the check, responded:

Mr. President, ladies and gentlemen:

I am conscious of my indebtedness to my friends in America who, for the second time, with great kindness and understanding, have gratified one of my dearest wishes. I feel deeply the importance of what has been said by the President of the United States about the value of pure science; this has been the creed of my life. Scientific research has its great beauty and its reward is itself, and so I have found happiness in my work. It has been, however, an additional, as well as [an] unexpected happiness to know that my work could be used for relief in human suffering. I do not believe that I deserve all the praise that has been given me, but I highly value the friendly feeling expressed by the President and by Dr. Welsh.

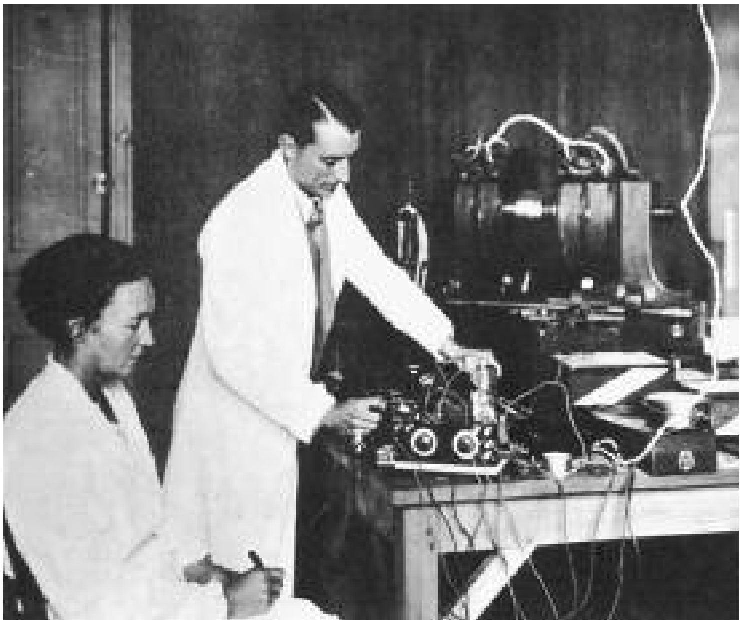
Mr. President, in my native land your name is revered for having saved, by your humanitarian work, a large part of the young generation. Your kind words of today will add to the gratitude of the Polish people toward you. In accepting this precious gift, which will hasten the opening of the Radium Institute in Warsaw, I offer you, and all my American friends, my most profound thanks. My laboratory in Paris will keep in close relation to the Warsaw Institute, and I will like to remember the American gifts of radium to me as a symbol of endearing friendship bridging your country to France and to Poland.[1]

Marie Curie's Legacy

In 1932, Madame Marie Sklodowska Curie returned to Poland to dedicate, along with her sister Bronya, the Warsaw Radium Institute. It was to be her last journey to Poland.

In the years that she directed the Paris Radium Institute, she was to develop hundreds of young scientists who were privileged to work with her. The Pierre Curie Radium Institute became the top international center for the study of radioactivity, with its main rival being the Cavendish Laboratory, headed up by Sir Ernest Rutherford. In Paris, however, Marie chose researchers from all over the world, and she always made sure that women were included.

Many of the scientists who worked with Marie Curie made their own important contributions. In 1929, Salomon Rosenblum, using radioactive actinium, which Marie herself had prepared for him, found that alpha particles were not all emitted with exactly the same energy. Paralleling similar findings for emitted light, this helped to confirm the existence of the quantum and implied that analysis could reveal the internal structure of the nuclei giving off the alpha particles. Fernand Holweck confirmed that X-rays are a form of radiation similar to light. Bertrand Goldschmidt



Roger-Viollet

Irène Curie and her husband, Frédéric Joliot, the discoverers of artificial radiation, at their laboratory in the Radium Institute.

1. I found the handwritten speech by Marie Curie in the Meloney Collection at Columbia University, with corrections made in her hand. I took the liberty of correcting a few spelling errors, and of leaving what she had crossed out, out of the speech. I have not seen either her speech, or that of Hoover, published anywhere else.

The Promise of Nuclear Power As Seen from 1967

Nuclear scientist Dr. Glenn Seaborg's remarks at the centennial celebration of Marie Sklodowska Curie's birth, included the following review of the economics of advances in nuclear power:

Artist's depiction of a nuplex, a nuclear-centered agro-industrial complex. This 1960s design was located on the seacoast for the purpose of desalinating seawater, as part of what Seaborg called a "food factory." In the "Atoms for Peace" optimism of the 1960s, it was assumed that nuplexes would be used throughout the world for development.

> While abundant and low-cost energy is not the only key to a nation's well-being, I believe it plays a most important part in the progress of a country. . . . In my talk last year before the British Nuclear Energy Society, I graphically plotted the world's population growth, superimposed the even greater growth rate of total worldwide energy demands. The results demonstrated clearly, from a statistical point of view, just how essential an abundant source of electric power is going to be to the world.
>
> If we examine the possible effect of abundant low-cost energy on developing nations, assuming that many modern technologies and the education to use them can be accrued at the time this energy is made available, we can see these developing nations making remarkable leaps into the mainstream of the 20th Century and beyond. In fact, as I will point out shortly, large nuclear energy centers may be the key to rapid development for many nations in the next few decades. . . .
>
> Let us look first at how nuclear energy might play a role in meeting one of man's most urgent problems—that of producing sufficient food to feed a rapidly growing world population. . . . Among them are land, water, seed, fertilizer, pest control, and the processing and distribution of the food. Nuclear energy can have a significant bearing on all of these. . . .
>
> [D]esalting of seawater on a large scale now appears economical through the use of nuclear power. In the United States we are about to begin construction on a dual-purpose nuclear station that will eventually generate about 1,800,000 kilowatts of electricity and distill 150 million gallons of ocean water per day. . . . However, if one thinks in terms of the large breeder reactor plants of the future, or even of large near-term dual-purpose plants. . . one can conceive of a nuclear complex producing much greater amounts of fresh water—some day perhaps billions of gallons per day at a cost of 2.5 cents per cubic meter. . . This begins to bring the cost of desalted water down to the range where it might be considered for some types of agriculture. . . .
>
> Another factor considered in this thinking is the possible economic production of large amounts of ammonia and phosphorous-containing fertilizer through the production of hydrogen by the electrolysis of water and electric furnace production of phosphorous. Motivated by these ideas, serious studies have been made . . . this past summer at Oak Ridge National Laboratory. . . .
>
> The study sees the development of large nuclear-powered agro-industrial complexes on coastal desert areas as "food factories." [T]he planning, construction, and operation of such a large nuclear agro-industrial complex would be no small undertaking and might best be done on an international basis—through advanced nations cooperating with developing countries. . . . [Such a food factory] capable of generating 1,000,000 kilowatts of electricity and desalting 100 million cubic meters or 400 million gallons of water per day . . . could support the daily production of

2,000 tons of ammonia and 360 tons of phosphorus. The food factory in this plant would consist of 200,000 acres irrigated and fertilized by the nuclear plant. . . . [I]t is projected that this complex could produce more than 1,000,000,000 pounds of grain annually, enough to feed almost 2,500,000 people at a caloric level of 2,400 calories per day. In addition, it could export enough fertilizer to other agricultural areas. . . to cultivate 10,000,000 more acres . . . [and provide] from 15,000,000,000 to 45,000,000,000 additional pounds of grain—enough to feed tens of millions of people at the same substantial caloric rates. . . .

Seaborg further elaborates the need for nuclear energy by describing many other projects that could be developed for the underdeveloped sector with it: Creating ports on the seacoast; new fishing industries, preserving fish with irradiation; nuclear-powered industrial complexes that can reduce iron, make steel, ferro-manganese, phosphorous, calcium carbide; using nuclear-powered electricity for electrolysis to make copper, using electrolytic hydrogen to create nitric acid and iron. He says that this can become the basis for a "self-sustaining growing economy in a reasonable number of years."

What would it take to do all this? Seaborg says:

> It would require great advance study from a technical, economic, and social standpoint. It would require a massive infusion of capital into an undeveloped area. And it would take, above all, the devotion and hard work of a great many talented people to put the plan into operation, to train operating personnel on all levels, and to establish a community that could successfully carry on such an undertaking once the initial corps of experts had left. Many people, however, envisage such a program as a potentially important step towards a lasting world peace.

Seaborg's enthusiasm does not end here, however. He continues to describe other needs for nuclear power. In one idea, he describes how nuclear power can be used to bring underground water resources to the surface for irrigation, using electrically operated tube-well pumps. He describes one study that had begun in India, in the Indo-Gangetic Plain, to bring underground water up, so that relying on monsoons for irrigation would be ancient history; the electrification of the underdeveloped villages with heating and air-conditioning; discovering ways to use radiation for pest elimination; saving trees by developing new metals, polymers, plastics, etc.; eliminating "junk" and waste by using nuclear-powered reprocessing; better ways to control and predict the weather; using nuclear-power to reach planets and other stars; better ways to develop nuclear medicine; using radiation in medicine to develop vaccines to stop disease; and ideas about radioisotope heart pumps to save lives.

aided the development of the atomic bomb by the United States by extracting polonium from old radon tubes. And Marguerite Percy became world famous in 1939, when she discovered the radioactive element francium while studying actinium.

Madame Curie's proudest moment was to see her daughter and son-in-law, Irène and Frédéric Joliot-Curie, successfully discover how to artificially produce radioactivity, when they used alpha particles to bombard aluminum. Frédéric Joliot-Curie, seeing the significance of this discovery stated that "scientists, building up or shattering elements at will, will be able to bring about transmutations of an explosive type." When Marie Curie and Paul Langevin came into the laboratory, and the couple explained what they had done, Marie was overwhelmed. Later, Frédéric Joliot-Curie said of that moment:

> I will never forget the expression of intense joy which overtook her when Irène and I showed her the first [artificially produced] radioactive element in a little glass tube. I can see her still taking this little tube of the radioelement, already quite weak, in her radium-damaged fingers. To verify what we were telling her, she brought the Geiger-Muller counter up close to it and she could hear the numerous clicks. . . . This was without a doubt the last great satisfaction of her life [Quinn 1995, pp. 429-430].

Madame Curie's legacy did not disappear with her death on July 4, 1934. One of the most magnificent, and least well-known celebrations of her life, was a scientific symposium in Warsaw, Poland, honoring the centennial of her birth in 1967. The best scientific minds of the world came together to pay homage to the woman who gave birth to the nuclear age. Despite the fact that the symposium took place in the middle of the "cold war" era, the delegations from the United States and the then-Soviet Union, gave the most magnificent tributes to Marie, and opened up a beautiful "dialogue" on the need for cooperation in nuclear research for world-development purposes.

On the Russian side, were two top Soviet Academicians: Andronik M. Petrosyants, Chairman of the State Committee for the Utilization of Atomic Energy, and Venedict Petrovich Dzhelepov, who was one of the founders of the Soviet national high-energy physics research center, and Director of Laboratory Problems from 1956-1984. Their joint speech was titled "Advances in the Development of Elementary Particle Accelerators in the Soviet Union," and in it, they describe the history and latest advances made by Soviet scientists in this field. In reverence to the memory of Marie Sklodowska Curie they said (in part):

> After the tragic death of Pierre Curie, his wife, Maria Sklodowska Curie, continued their investigations with great success. She boldly pioneered the road to the "terra incognita" of the micro-world, where everything was mysterious and unusual . . . tackled a wide range of problems, including the search for radioactive ores, the development of techniques for separating microscopic

amounts of radioactive elements and for studying their physical and chemical properties, the production of large quantities of radium . . . the performance of high-precision thermal measurements, the development of fundamentally new measuring methods and equipment, and the careful study of the properties of the various forms of radiation. . . .

Sparing no effort and sacrificing her health, Marie Curie not only increased the depth and scope of scientific research, but also ensured that her young colleagues received careful training. Frédéric Joliot and Irène Curie, outstanding scientists whose names are known throughout the world, were trained by Marie Curie. Scientific contacts with Marie Curie and her co-workers were maintained by a number of Soviet scientists: Academicians V.I. Vernadsky and D.V. Skobeltsyn, who had in their early years worked for a long period under her direct supervision in Paris; Academicians V.G. Khlopin and P.L. Kapitza; L.S. Kolovrat-Chervinsky, the prominent physicist, who had been one of her pupils; Z.V. Ershova, the well-known Soviet radiochemist, who had been a member of the scientific team established by her.

Marie Curie's services to science were greatly esteemed by the Russian people, and in 1907 she was elected corresponding member of the Petersburg Academy of Sciences. In 1928, she became an honorary member of the USSR Academy of Sciences. Soviet scientists began studying the problems of radioactivity and the atomic nucleus soon after the establishment of their young State. In the early 1920s, Academicians V.I. Vernadsky, V. G. Khlopin, and A.F. Ioffe established scientific centers for the direct study of these problems. Like Marie Curie, they foresaw the significance of such problems for the future of mankind.

It is impossible to overestimate the value of Marie Curie's services to science. Her investigations and discoveries resulted in a chain of new, fundamental investigations giving rise to a revolutionary change in ideas regarding the structure of matter. . . .

At the close of the Academicians' presentation on particle accelerators they said:

We see this as the way to the realization of the dream of a society where people are brothers, where there are neither wars nor poverty, and where all the intellectual and material needs of mankind are satisfied. . . . In its gratitude mankind honors Maria Sklodowska Curie, a genius who devoted her entire life to science and to mankind. The memory of the great achievements of Maria Sklodowska Curie, the only person to be awarded the Nobel Prize twice, will live forever. The Polish people cherish the name of their great daughter who, in gratitude to her Polish motherland, dedicated to it her discovery of a new element, naming the element "polonium." Polish scientists are continuing the glorious traditions of their celebrated compatriot and enriching science with new discoveries. We should like, on this solemn occasion, to wish our friends, the scientists of Poland, further success in the field of creative research, bringing still greater glory to their cherished motherland.

'Nothing in Life Is to Be Feared It Is Only to Be Understood'

The American representative at the Warsaw Conference was Glenn T. Seaborg, who was chosen by President John F. Kennedy, to head the Atomic Energy Commission in 1963, a post he held through two more presidencies. Seaborg won the Nobel Prize in Physics for his discovery of plutonium and seaborgium. He worked on the Manhattan Project during World War II, and discovered a number of radioisotopes to treat cancer. In the years after this excerpted 1967 speech in honor of Marie Curie's 100th birthday, Seaborg met with his eminent Russian colleagues, Dzhelepov and Petrosyants, at various scientific symposiums, and headed the American delegation at the Flerov Laboratory of Nuclear Reactions in August 1971.

Seaborg's scientific outlook represented the very best of American cultural optimism, which is alive today in the person of Lyndon H. LaRouche, and his associates. His speech was titled: "Future Outlook for the Applications of Nuclear Science":

Courtesy of Lawrence Berkeley National Laboratory

Dr. Glenn Seaborg (center) visiting Marie Sklodowska Curie's house in Warsaw in 1967, when he was the U.S. representative at the centennial celebration of Marie Curie's birth. With him are centennial participants W. Billig and Albert Ghiorso.

I believe that we have gathered here basically for two reasons. The first is to pay tribute to the memory of a pioneer in our field, a noble lady whose contributions to chemistry, physics—and, in general, to the spirit and progress of all science-must be recalled and celebrated on this centennial anniversary. The second reason is one based on a belief that Maria Sklodowska Curie held during her lifetime—and, were she alive today, one about which I am sure she would feel even more strongly. It is the belief that we who are privileged to be scientists, to be engaged in the pursuit of universal truths, are continually obligated to share our scientific heritage and, to the best of our ability, see that our science serves the greater good of mankind. I think we are succeeding in these areas. But I also believe, and I think you will agree, that never before has there been so urgent a need for a stronger bond among the world's scientists and for their cooperative efforts in translating scientific progress into human progress throughout the world. . . .

"Nothing in life is to be feared—it is only to be understood." Here, Marie Curie a few weeks before her death.

Many years before the birth of the Nuclear Age—to which her work contributed—Marie Sklodowska Curie wrote: "Nothing in life is to be feared—it is only to be understood." Today we stand on the threshold of a new age—one in which a greater understanding and use of the nucleus of the atom and its peaceful potential could more than replace the fear in which most men hold it. It could provide a world willing to work cooperatively with an enormous and most versatile force for progress. In some respects the most remarkable thing about our understanding of the nucleus of the atom—our nuclear science—is its range of influence on other sciences and technology.

Seaborg then forecasts that "by 1980 nuclear power will be generating about 150,000,000 kilowatts of electricity in the United States" and says that "we must not overlook the potential for controlled fusion" (see box, p. 64).

In his final remarks in Warsaw, Glenn T. Seaborg said:

Finally, let me add this thought concerning the internationality of science and man. This is a belief that Maria Sklodowska Curie held strongly and one that I think is shared by this symposium. All of what I have projected today that is hopeful and could advance the progress of mankind—all this and so much more—could be realized and perhaps sooner than we think, if we in science could effect one "human breakthrough"—if we could somehow convince our fellow men that we now live in an age when fear, mistrust, and blind passions based on and regenerated by past ignorance and error must give way to a new ideal of understanding and reason among men. We live on the threshold of a new age made possible by the pursuit of—above all—truth. That pursuit has carried man with an ever-quickening pace through centuries of darkness. Now the light of truth glows brighter than ever. It is a beacon that shines into the future —a future that can be our own choosing. We must not turn our backs on that possible future. We as scientists and citizens of a greater community of man must help our fellow men to see the light. Maria Sklodowska Curie said: "Nothing in life is to be feared—it is only to be understood." Now is the time to understand more—so that we may fear less.[2]

Marie Sklodowska Curie's entire life's work is the story of the passion to discover scientific truth for the betterment of mankind. It is a life filled with self-sacrifice, curiosity, creativity, and love for humanity. It is little wonder that the scientists at the Warsaw Symposium, who came together to honor her life's work on her 100th birthday, had such praise for her as a scientist, and as a human being. It is aptly expressed in the ideas that they speak of, and their unbridled optimism to use scientific discovery to transform the physical universe.

Her life, in particular, her two visits to the United States, where she was revered by Americans, men and women alike, should serve as a reminder to us, that we, as a nation, are a much better people than we now show ourselves to be. Her life should serve as an inspiration, and a reminder to us that we need to turn to scientific truth, and fight for cultural optimism in this time of crisis. This is the best way to honor her memory, in this 100th anniversary of the first Nobel Prize she received. Americans, at their most magnificent, have been a people of great generosity, not simply with their wealth, but with their spirit for discovery and technology. We can no longer afford to be a "little people," and a people filled with terror for the unknown. An American who thinks like that could never have built this nation, nor set foot on the Moon.

We must begin to use our collective creative imagination to solve the problems besetting the world. We have to envision what the world should look like, and then do the hard work to make it a reality. As Pierre Curie wrote in his personal journal at the age of 21, in 1880: ". . . one must make life into a dream and make the dream into a reality."

Denise Ham is a long-time associate of Lyndon H. LaRouche, Jr.

2. These speeches are excerpted from the *Marie Sklodowska Curie Centenary Lectures, Proceedings of a Symposium,* Warsaw, October 17-20, 1967, Organized in Poland by the Marie Sklodowska Curie Centenary Committee in cooperation with the Atomic Energy Agency and UNESCO, Published by International Atomic Energy Agency (Vienna, 1968).

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Notes

* Can be accessed on the internet