

Marie Skłodowska-Curie: teacher, mentor, research center founder, and “la Patronne”

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Abstract. This year (2011) marks the 100th Anniversary of the award of the Nobel Prize in Chemistry to Marie Skłodowska-Curie for her discoveries of radium and polonium and her studies of their properties. The United Nations has proclaimed 2011 as the “International Year of Chemistry”, partly in recognition of this 100th anniversary. A resolution of the Sejm of the Republic of Poland has also established 2011 as the Year of Maria Skłodowska-Curie. Marie Curie has been celebrated this year by a host of prestigious societies and in many countries all around the world for winning Nobel Prizes in both Physics (1903), for the discovery of radioactivity together with husband Pierre Curie and Henri Becquerel, and Chemistry (1911). She was the first woman to win Nobel Prizes in both Physics and Chemistry and the only one to date to win prizes in both physics and chemistry. Also remarkable was that after Pierre Curie’s tragic and untimely death in 1906, she was put in charge of his lectures and laboratory, thus marking the first time in France that a woman occupied such a prestigious academic position, and opening the way for other women to follow. The current article will focus on some of the other notable accomplishments of Marie Curie that are not as commonly recognized, including her organizational and persuasive abilities, and her unique contributions as a teacher, mentor, research center founder, and laboratory “la Patronne”.

Key words: 1903 Physics Nobel Prize • 1911 Chemistry Nobel Prize • marriage of Maria Skłodowska and Pierre Curie 1895 • polonium and radium discoveries 1898 • 1906 death of Pierre Curie • Laboratory Director 1904–1934

Introduction

Special honors

Marie Skłodowska-Curie is probably best known to scientists as the winner of two Nobel Prizes, the first one in Physics in 1903 for the discovery of radioactivity which she and husband Pierre Curie shared with Henri Becquerel, and the second in Chemistry in 1911 to her alone. We are celebrating the 100th anniversary this year of her momentous Nobel Prize in Chemistry given “in recognition of her services to the advancement of chemistry by the discovery of the elements radium and polonium, by the isolation of radium and the study of the nature and compounds of this remarkable element”.

She was subsequently to be highly acclaimed for her use of radium in medicine and is probably best known to non-scientists for applications of radium and X-rays in medical diagnostics and therapeutic medical treatments.

Her unshared receipt of the Nobel Prize in Chemistry is remarkable not only because she was the first woman to receive the Nobel Prize in Chemistry (one of only 4 women) but the only scientist to receive Nobel prizes in both Chemistry (1911) and Physics (1903). The only

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four women to date who have received Nobel Prizes in Chemistry are: Marie Curie (1911), Irene Curie (shared, 1935), Dorothy Crowfoot Hodgkins (1964), and Ada E. Yonath (shared, 2009). Only two women have received Nobel Prizes in Physics: Marie Curie (shared, 1903), and Maria Goeppert-Mayer (1963, shared).

Early career aspirations

Maria Salomea Skłodowska, the 5th child of Władysław and Bronisława Skłodowski, was born in Warsaw, which was then under Russian occupation and Poland did not exist as an independent country. She came from a family of teachers who valued education very highly and she herself was a brilliant teacher and devoted to improving the lot of Polish students who suffered under Russian domination of Poland. Her father was a teacher of physics and mathematics and her mother was the headmistress of a private school while bearing five children in eight years, but died of tuberculosis when Marie was very young. Marie managed to graduate from the state school with honors at 16, but at that time in the Russian empire, higher education was not available to women, so she and older sister Bronia made an agreement that Marie would try to provide financial aid to Bronia for medical studies in Paris, and later Bronia would help Marie move to Paris to study. Marie took various positions as governess and tutor in the countryside as well as in Warsaw, also giving lessons with her father in order to support Bronia. In the evenings Marie worked in the laboratory of the Warsaw Museum of Industry and Agriculture where she learned qualitative and quantitative analysis, the chemistry of minerals and a variety of other useful procedures. This experience convinced her that she was interested in experimental research.

Finally, after having struggled emotionally and financially, she left her widowed father behind in late 1891 and joined Bronia and her husband in Paris. She was already 24 by the time she was able to register at the Sorbonne to study for a Master's degree in Physics. She found herself rather ill-prepared and studied constantly, to the detriment of her health, but got the highest score in the 1893 Physics Master's exam and received a small scholarship enabling her to continue her studies. She then received the 2nd highest score in the Mathematics exam in 1894. That same year a Polish professor arranged for her to meet Pierre Curie whom he thought could help Marie with a small research project she was pursuing, and it soon became clear that they had much in common. Marie changed her mind about returning to Poland to teach, and Marie and Pierre were married in July, 1895.

Marriage, scientific collaboration, and children

Marie and Pierre Curie then began a productive, nearly ideal life of scientific collaboration along with a satisfying family life. Marie was allowed to work in the same school (most unusual for that time) where Pierre was a professor and had his laboratory. Marie prepared for the national exams for teaching positions at secondary schools but never applied for a position. Instead, a few

weeks after the birth in September 1897 of first daughter Irene, Marie decided to perform thesis research on the new radiation recently discovered by Henri Becquerel. Marie and Pierre subsequently discovered polonium and radium and reported these in notes to the French Academy of Sciences in 1898. She defended her thesis entitled "Researches on radioactive substances" at the Sorbonne in 1903. It was widely published and that same year the Curies were notified that they would share the 1903 Nobel Prize in Physics with Becquerel for their research on radioactivity!

The news that the Curies and Becquerel were to receive the Nobel Prize in Physics was reported as early as December 1903, but received little publicity in the French press until much later in the year. The first Nobel Prizes in Physics awarded in 1901 and 1902 had attracted little attention. However, once the French press realized that the "Curies" were French and a married couple they gave tremendous publicity about the 1903 Award that went to the "Curie couple" together with Becquerel, and this really caught the public's attention. People were especially fascinated with radium and its unusual properties which were not yet fully understood, and Marie was even called 'Our Lady of Radium', Ref. [5, p 195] by some.

Neither one of the Curies accompanied Becquerel to Stockholm to accept the Prize which might have been considered a serious affront by the Swedish Academy but they both believed they had legitimate reasons for not embarking on the long, cold journey to Stockholm. Marie had suffered a miscarriage (attributed to overwork) in August 1903, and was still not well which kept her from traveling. Pierre, in addition to being in rather poor health, felt he could not stay long in Stockholm and must quickly get back to his teaching duties.

However, all around the world there was a fascination with radium and its properties, both for causing burns and health problems and for curing cancers! In her biography of Marie Curie, Susan Quinn devotes an entire chapter, Ref. [5, pp 187–209] to a discussion of "The Prize" and the ensuing notoriety and public attention that was focused on the Curies.

Nevertheless, the unexpected Nobel Prize money greatly improved the Curie's financial situation. Pierre became a full professor at the Sorbonne and Marie was appointed as his assistant, her first official position. However, the overwhelming publicity associated with the Nobel Prize Award tended to disrupt their research as well as their family life! Other honors were offered to them, but what Pierre and Marie wanted most urgently was improved and larger laboratory facilities.

Then began a hiatus in the Curie's research not only because of disruption due to the publicity, but perhaps even more importantly because Marie wanted to fully recover her health. This time, during her pregnancy with second daughter Eve, she was occupied with trying to take care of her own health and attend to the many illnesses which daughter Irene was suffering, in addition to being concerned about Pierre whose health was still deteriorating. Fortunately, daughter Eve Denise born on December 6, 1904 was a strong, healthy baby, destined to live until she was nearly 103! In spite of Marie's continuing intense involvement in her research, the welfare and progress of Irene and

Eve were of paramount importance to her at this time, and she personally continued to oversee their health and general well-being and education. She wondered if she could manage it all and engaged a nanny, a maid and, in addition, Pierre’s father helped out a great deal with his grandchildren and provided a steadying influence for all of them. Marie’s family in Poland was also of great concern to her. She continued to remain close to them and to visit with them as frequently as possible.

By early 1905, Pierre and Marie Curie felt they were able to travel to Stockholm. They found it nearly deserted during the June vacation time which they much preferred because their visit attracted less publicity and there were no huge crowds to deal with and they could enjoy the pleasant countryside. Pierre’s lecture on their behalf was given to the Swedish Academy on June 6, 1905. It was very brief (only 6 pages long), but was also very perceptive, mentioning applications of radioactivity, not just in physics, but in chemistry, geology, meteorology and biology. In his discussion of their contributions to the discovery of radioactivity he mentioned Marie’s contributions many more times than his own. He especially highlighted her studies of various minerals containing uranium or thorium and discussed the concepts of half-life and induced radioactivity and described various experiments. He pointed out that although radium and its rays and emanations can be used to treat certain diseases they can also create sores which are difficult to heal and that prolonged exposure could even lead to paralysis and death! His final paragraph has become one of the most widely quoted excerpts from any Nobel Prize lecture. He concludes that even though new discoveries can constitute “a terrible means of destruction in the hands of great criminals” that “I am one of those who believe with Nobel that mankind will derive more good than harm from the new discoveries” [2]. Marie and Pierre’s life then apparently settled into a pleasant and productive schedule of performing experiments designed to answer questions concerning the rapidly developing world of radioactivity, interspersed with Marie often spending a few days in the countryside near Paris with the children when the weather was favorable, or when she felt they (or she) needed a respite from the city and their busy life. Pierre did not often accompany them as he was too occupied with his research even though he was still in rather poor health. Most unexpectedly, this pleasant and satisfying life style for Marie and the children came to a tragic end on Thursday, April 19, 1906. Pierre attended a meeting a mile or so across Paris from their home *without Marie* for an Association of Professors meeting. When he left in the early afternoon, it was raining and as he later crossed a street – perhaps without looking carefully or maybe with the view obstructed by his umbrella – he was run over by a heavy horse-drawn wagon, and killed instantly. Maria had taken Irene to Fontenay-Aux-Roses on an outing for the day and did not hear of the horrible accident until nearly seven in the evening. As later related in her journal her first reaction was disbelief. She was totally distraught, and felt that her life and her science were over; for years afterward she could not even speak of Pierre to the children, Ref. [3, pp 5, 10].

Marie Curie becomes laboratory director (la Patronne)

After Pierre Curie’s untimely death, Marie quickly refused an offer from the French government of an annual pension as Pierre’s widow, saying that she was 38 years old and could work, but what she really wanted was a laboratory where she could continue her research, Ref. [3, p 10]. The council of the Faculty of Science decided to bestow Pierre’s chair on Marie and even made her director of his laboratory as well, thus beginning her long career as a laboratory director. She soon resumed her work, emphasizing radiochemical research, calibration of radium sources, and the preparation of the first radium standard. Two years later she was appointed to be a full professor! In retrospect, it seems truly remarkable, that after Pierre’s untimely and tragic death in 1906, Marie was put in charge of his lectures and laboratory. *Thus, for the first time in France, a woman was allowed to occupy such a prestigious position, thus opening the way for other women to follow.* She was not a “militant feminist” in the usual sense of the words, but did strongly believe that women had the same potential intellectual capacity as men, Ref. [3, pp 4, 5], and as her laboratory grew it included ever larger numbers of women researchers, Refs. [1, 3–5]. There is no evidence that Marie Curie treated women any differently than men in her laboratory, or encouraged them any more or any less, but she did hold all to a rather strict work ethic. Perhaps the fact that she did treat women equally was the reason for the rather large number of women in her laboratories. The research was arduous as she focused more and more on the purification of the radioactive elements, their discovery and characterization, and the preparation of increasingly intense radioactive sources. On the other hand, if some of her staff were ill or needed help, she did everything she could to help them with their problems. It was probably during these early years that she was first called “la Patronne” by the laboratory personnel, as the feminine form of “patron” which in our English dictionaries is defined as derived from the Latin, and refers to defender, protector, advocate, or supporter, all of which certainly applied to Marie Curie’s style as Laboratory Director!

Even before Pierre’s death the Curies had begun to investigate applications of radioactive elements in the field of medicine and their possible industrial production. Under Marie’s leadership the decision was made to specialize in the purification and study of radioactive substances because it was often difficult for researchers in the field to obtain radioactive materials for use in their research and the quality of the offered products was sometimes in doubt.

After only a few years, Marie had increased the number of workers in the small laboratory from 7 to 24 and had obtained some funding from the Carnegie Foundation. She had replaced Pierre’s lab assistant and was showing herself to be a proficient, no-nonsense administrator. She increased her international role in keeping records in the field of radioactivity. In 1910 an international commission adopted the “Curie” as the international unit of measurement for radioactivity and Marie Curie was asked to prepare a radium standard which would serve to calibrate radioactive sources for both research and applied work.

Marie also collected radioactive minerals for the laboratory's collection, both from her own travels and from those of others. As time went on the research of her laboratory was focused more and more on the "radioactive elements" rather than on unraveling the mysteries of the nucleus. Thus not only did she originally coin the word "radioactivity" for the initial phenomenon discovered by Becquerel, she also became the founder or "mother" of radiochemistry. Perhaps it is understandable then that the language of radioactivity seems to be feminine – mother, daughter, etc.

Guillamont and Brambow, Ref. [3, pp 24–27] discuss how radiochemistry became a part of chemistry and state that "The discovery of polonium and radium and the course of chemistry and society would have been different were it not for the extraordinary patience, determination, and curiosity of Marie Curie as she searched for the origin of the strong radiation from uranium compounds. Her unwavering belief in the hypothesis of radioactivity as an atomic property and her spirit of adventure and readiness to pursue unorthodox thinking, changed the course of history".

The Award of the 1911 Nobel Prize in Chemistry to Marie Curie as the *only* recipient is an amazing story. It has been thoroughly discussed by granddaughter Helene Langevin-Joliot, Ref. [3, pp 4–6; 8–10]. She points out that at the time of Marie's discoveries of polonium and radium a century ago, it was exceptionally difficult for a woman to be recognized for her scientific achievements without encouragement from "a father, husband or brother". She further concludes that Pierre's "simple act of placing only Marie's signature" on the April 1898 note to the French Academy of Science concerning her decision to investigate minerals and compare the radioactivity of natural samples with that of an artificial one (using the apparatus set up by Pierre) was crucial to the Award of the 1911 Nobel Prize to Marie alone for the discovery of radium and polonium and the elucidation of the properties of radium! Pierre's decision was most unusual since Marie was only a PhD student who had benefited greatly from his advice and help. Since they were already working together, tradition would have decreed that the "supervising" professor should also sign the note, as is still customary in academia today. Langevin-Joliot also discovered when the Nobel Prize Committee's archives were opened they revealed that on the suggestions of the French Academy of Sciences, the 1903 Committee for Physics first considered naming only Becquerel and Pierre Curie as recipients. However, when Pierre was told about this privately by a Swedish colleague he insisted that Marie must be included. A rather strange and very important consequence of this was that because the 1903 Award made no mention of the discovery of radium it was possible for Marie to win a second Nobel Prize in 1911 – this time for Chemistry! And that Award had the effect of making Marie Curie the *first celebrated woman scientist in the world!* Her receipt of the 1911 Nobel Prize in Chemistry is remarkable not only because she was the first woman to receive the Nobel Prize in Chemistry (and one of only 4 women to date), but she remains the only scientist to date to receive Nobel prizes in both Chemistry and Physics. It almost appears that Pierre had thought and worried about Marie's future with a prescient insight

or premonition of potential future problems she might encounter.

During and after winning the Nobel Prize in Chemistry in 1911, Marie was under extreme duress and pressure to resign as head of her small laboratory in Paris due to the notoriety and adverse publicity that erupted in the French newspapers concerning an alleged "affair" with colleague Paul Langevin after Pierre's death. An alternative to remaining in Paris was promptly (1913) offered to Marie by a delegation from the Warsaw Scientific Society asking her to return to Warsaw to continue her research there. Although she accepted the position of honorary director of the Radiological Laboratory in Warsaw and continued her interactions with that Laboratory, she chose to remain in Paris. However, Marie believed that her small laboratory in Paris was not large enough to accommodate the increasing number of scientists interested in pursuing research in radioactivity. Instead of resigning, she again demonstrated her determination, fortitude, single-mindedness, and persuasive abilities by campaigning to construct a new larger facility in Paris! Almost unbelievably, the campaign succeeded in 1912 and construction of the Radium Institute in Paris began. It was nearly completed when World War I (WW-I) broke out in 1914. Marie Curie's main pursuit then turned to the organization of X-ray diagnostics and services for the military hospitals in France, again showing her devotion to France, her adopted country, Ref. [3, pp 10, 11].

Humanitarian role of Marie and Irene Curie during World War I

The earliest collaborations of Marie Curie with the medical profession involved not radium, but the use of X-rays. In order to aid the military health service which could not fill the demand for medical X-ray diagnoses, Marie was involved in setting up X-ray facilities in hospitals where wounded soldiers were taken. Daughter Irene (only 17 years old) became a full-time partner in all of these activities and was treated as an "equal" by Marie. She not only helped in examining the wounded, but organized training courses for nurses and doctors in the proper techniques to be used in locating bullets in the wounds.

Marie advocated and pioneered the construction and use of mobile X-ray units and as a result of her advocacy and her considerable teaching and management skills, dozens of miniaturized "radiological" cars called "Petites Curies" (Little Curies) were designed and built. These were light and mobile and could be taken to the front lines to help diagnose wounded soldiers, Ref. [3, pp 3, 36]. As soon as Marie was able to obtain her license as an ambulance driver, she and Irene took their first trip alone to the battlefield in 1914 in one of these cars!

Return to the Institut du Radium

As described earlier, the University of Paris and the Pasteur Institute had planned and constructed the new interdisciplinary institute for research and applications

of radioactivity, the Institut du Radium, prior to WW-I. It had two sections: the Curie Pavilion directed by Marie Curie and devoted to the study of the physics and chemistry of the radioactive elements; and the Pasteur Pavilion directed by well-known medical researcher Claudius Regaud to concentrate on biochemical and medical applications of radioactivity. Normal operations began when Marie, together with Irene as her Assistant, returned after the end of WW-I. Irene was sometimes referred to as the “Crown Princess” by co-workers, Ref. [4, pp 127–129] because of her authoritative and somewhat intimidating manner, unbelievable knowledge of physics and mathematics, and privileged access to Marie Curie.

In 1920, Marie Mattingly Meloney (known to all her associates as “Missy”), a journalist and editor for a popular U.S. women’s magazine, *The Delineator*, finally managed to obtain an interview with Marie in her Paris Laboratory. Despite the extreme differences in their temperaments and their different philosophies, they began a friendship which lasted throughout their lives. Marie Curie told Missy of the funding problems of her Laboratory in Paris in a country still recovering from the ravages of WW-I, and that they no longer had access to radium for their research as their entire supply was being used in the biological section for cancer therapy. She pointed out to Missy that the U.S. had the world’s most plentiful supply of ~ 50 grams of radium! Missy decided not only to get a story for her magazine, but to use her influence and contacts to purchase and give a gram of radium which cost ~ 120,000 U.S. dollars to Marie for her research. Missy not only publicized this widely in her women’s magazine but served as Chair of the Marie Curie Radium Fund and enrolled a host of prominent women and men to help in the fund-raising campaign, Ref. [3, pp 15–19].

In May 1921 a contract was negotiated with the Standard Chemical Co. of Pittsburgh, Pennsylvania for a gram of radium at the reduced price of \$ 100,000.00 in Marie’s honor. Missy then persuaded Marie (accompanied by daughters Irene and Eve) to come to the U.S. on a whirlwind tour involving many receptions, press conferences, and visits. Marie and daughters Irene and Eve then undertook their first trans-Atlantic voyage, and arrived in New York City on May 1, 1921. They were met by large crowds as Marie Curie was well-known to the general public for her applications of radium, especially in therapeutic medicine. Missy protected Marie from overdoing as she was in rather fragile health, and Irene (23) and Eve (16) took over as many functions for their mother as they could. Together they visited numerous women’s colleges and Marie received honorary degrees from many prestigious U.S. universities. They also visited the Grand Canyon and the Colorado site where carnotite ore, the source of U.S. radium, was mined.

The highlight of the visit occurred on May 20, 1921 when Marie was received in the White House by President Warren G. Harding who presented her with a golden key to the small lead-lined mahogany box containing the one gram of radium which he then gave to her! When the deed for the radium was given to Marie making her sole owner of the radium, she requested that it should be amended to pass from her directly to her Laboratory, rather than to her daughters.

Marie and Pierre Curie’s original decision not to exploit their discovery of radium was often questioned by many of their associates who maintained that if the Curies had not been so magnanimous, they would have had ample means of financing their subsequent research and laboratories. However, in a talk delivered at the U.S. National Bureau of Standards during the 1921 visit, Marie stated that she still believed they had done the right thing. On June 25, after a very successful but grueling nearly two-month visit, Marie Curie and daughters left from New York with the radium, mesothorium, and thousands of dollars for support of the Radium Institute in Paris!

In the 1920s the number of people in Marie Curie’s laboratory increased to highs of 28 to 37 in 1922–1926 and averaged ~ 30% women but it was still difficult to obtain grants for women in the same numbers as for men, and women obtained fewer than 20% of the grants. Except for Irene Curie, no woman held the position of assistant. Most of the women stayed for only a year or two and a large fraction were foreigners, i. e., from countries other than France.

Irene regarded the 1921 fund raising trip to the U.S. as a welcome break to the regular routine at the Pavilion Curie. She had sometimes substituted for her mother in speaking and accepting honorary degrees, and spoke and received a few honorary degrees of her own, Ref. [4, pp 128–130].

During the 1920’s, the Curie Pavilion was recognized along with the Cavendish Laboratory in Cambridge, the Institut für Radium Forschung in Vienna, and the Kaiser Wilhelm Institut für Chemie in Berlin as one of the four main laboratories in the world with a primary focus on radioactivity research, Ref. [3, pp 12–15]. Irene Curie was one of only a very few experts on radioactivity in the 1920s, and the Pavilion Curie with its access to radium and polonium was ideal for her research on reactions of the alpha-particles emitted by polonium with non-radioactive materials.

In 1925, Irene Curie defended her dissertation at the Sorbonne. She spoke to the large crowd that filled the auditorium to listen to Marie Curie’s daughter describe her research on the reactions of alpha-particles emitted by polonium with non-radioactive targets. Her presentation warranted congratulations from her examining committee and also attracted world-wide attention from the news media, Ref. [4, pp 128–130]. She was asked by a French woman journalist if she thought a scientific career might be too taxing for a woman and what about family obligations. Irene was said to have replied that they were an added responsibility but that for her science would be the primary interest in her life.

Shortly thereafter, Marie accepted Frederick Joliot into her laboratory even though he had no previous research training. Although he initially received a rather cool reception, Irene Curie and Frederick Joliot soon began their studies of the reactions of alpha particles with non-radioactive target materials such as aluminum, Ref. [3, pp 25, 27, 34, 35] and married in 1926, Ref. [3, p 11]. Their studies were made possible because of access to the very intense alpha-emitter polonium. Radioactive phosphorus was produced according to the reaction: $^{27}\text{Al} + \alpha \rightarrow ^{30}\text{P} + \text{n}$. The Joliot-Curies confirmed their discovery by chemical separation of the short-lived

(~ 2 min) ^{30}P from the aluminum target foil. They were able to share the news of their landmark discovery of artificial radioactivity with Marie Curie shortly before her death on July 4, 1934. Irene and Frederic were awarded the Nobel Prize in Chemistry in 1935 for this discovery. *This is another first – the first and only example to date of a mother and daughter both receiving Nobel Prizes in Chemistry!*

Marie continued her interest and close association with the Polish Radium Institute over the years, Ref. [3, pp 38–41] and visited Warsaw many times and often emphasized how much she loved the country of her birth. Upon being awarded honorary citizenship of Warsaw in 1913, she said, “If Prof. Napoleon Milicer and his assistant, Dr Kossakowski, did not teach me analysis in Warsaw, I would never have separated radium”. Another dream of Marie was to build the Radium Institute in Warsaw, a twin institute to the one she had established in Paris – “My greatest dream is to build the Radium Institute in Warsaw”. In a biographical sketch by granddaughter Helene Langevin-Joliot and Jerzy Kroh, Ref. [3, p 11], we see a Cartoon Mural of Marie Curie in Warsaw in which, “I was born in Warsaw”, is proclaimed in large letters. In smaller print it says, among other things, that whenever she gave a talk she began by saying, “I was born in Warsaw”.

When Missy Meloney again visited Paris in 1928, Marie Curie asked her if the American people might be able to buy a gram of radium for the Polish Radium Institute in Warsaw. Missy was now editor of the *Sunday Magazine of The New York Herald Tribune* and she quickly began to organize a second trip. But she warned Marie that Americans had become “isolationist” and less magnanimous. Nevertheless, Marie arrived in New York City on October 15, 1929, Ref. [3, p 19]. The trip began on a very favorable note when newly elected President Herbert Hoover asked her to stay at the White House, another first for Marie Curie, as no other foreigner had previously been so honored! Marie’s sight was beginning to fail, but she still made many visits and her remarks at the American Society for Control of Cancer were broadcast on the radio. President Hoover presented her with a bank draft for \$ 500,000 during a ceremony on October 30, 1929, but the event was somewhat overshadowed by the stock market crash of October 29, 1929. Mdm. Curie accepted the gift for the Radium Institute of Warsaw saying that it would hasten opening of the Institute and that she will, “remember the American gifts of radium to me as a symbol of endearing friendship bridging your country to France and Poland”.

Retrospectives

Let us now take a careful retrospective look at the contributions and consider the legacy and role of Marie Skłodowska-Curie in the following categories:

Teacher. Maria Skłodowska came from a family of teachers who valued education very highly and she herself was early on recognized as a brilliant teacher and devoted to improving the lot of Polish students who suffered under Russian domination of Poland. Teaching remained of great importance to her throughout her life, as evidenced by her careful oversight of her own

daughters’ education. She continued teaching duties at Sévres girls school even after the 1903 Nobel Prize Award money meant that she no longer needed to teach to augment their income. She also took an interest in curriculum issues and added laboratory demonstrations and experiments to be conducted by the students. She wished to limit the long hours children spent in school which kept them from getting enough exercise, fresh air, and free time for ‘thinking’.

The year after Pierre’s death she even organized a ‘cooperative school’ taught by friends and colleagues and their spouses in their living rooms and experiments were performed in various accessible laboratories. The cooperative left ample time for outdoor activities and sports.

Mentor. Mentoring also continued to be of prime importance to Marie throughout her life and continued during her tenure as Director of the Curie Pavilion, Ref. [5, pp 404, 405]. She was often observed in later years sitting on the stairs in a hallway where researchers (including younger scientists) gathered to discuss scientific questions. It was important to her to be aware of what was going on in the large institute with its numerous laboratories and to not only inspire young scientists but let them choose their research directions and methods.

Research center founder. Marie Curie’s skill and determination in procuring suitable laboratory facilities and resources for accommodating the large number of scientists who wanted to pursue studies of radioactivity have been amply illustrated in the preceding Sections.

Laboratory director – “La Patronne”. In the article, “Marie Curie and Women in Science” by S. Boudia, Ref. [3, pp 12–15], Marie Curie is described as “an inspiring laboratory director”. Detailed information is given about the women who stayed in Marie Curie’s laboratory between 1906 and 1939 and the percentages of women in each year through 1934. The number of people in Curie’s laboratory ranged from lows of 8–11 in 1904–1908, to highs of 28–37 in the 1920s, to 44 and even 53 in the 1930s and just before Marie’s death in 1934! Initially the fraction of women was lower because the number of grants available to women was very small and many women worked almost for free in the early days. There were essentially no regular faculty positions available for women and, aside from daughter Irene Curie, no woman held the position of Marie’s assistant. However, it was possible for Marie to form a relatively stable more permanent group of researchers (~ 10) and half of these were women. After WW-I, the percentage of women increased dramatically as more funding became available from a wider range of sources. A total of 47 women worked there. Most of them stayed for a year or two, but some stayed for much longer periods of time. In addition to the 15 or so from France, the remainder of the women came from Austria, Canada, Greece, Hungary, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Russia, Sweden, Switzerland, United Kingdom, and Yugoslavia. Furthermore, these women were not simply given the more boring and repetitive tasks. Supporting evidence for this is the observation of the later successes of so many of them. A few examples are given below.

Sonia (née Slobodkine) Cotelte (Polish) specialized in preparation of radioactive sources and in 1926 was appointed to a special position created by the science faculties to support the Curie Laboratory and remained until 1945.

Ellen Gleditsch from Norway spent nearly 5 years with the Curie group (1907–1912) and, subsequently, returned from Norway for many shorter visits. Gleditsch was ultimately responsible for starting a Radiochemistry Chemistry group at the University of Oslo which formed the basis for the subsequent Nuclear and Radiochemistry group led by her former student, Prof. Alexis Pappas, who was known world wide as a pioneer and giant of nuclear chemistry for more than half a century.

Marguerite Perey (France) discovered the new element with atomic number 87, which she named “Francium” after her native country. She began as a test tube washer in Curie’s laboratory in 1929, but went on to isolate element 87 from “natural” sources, as the 22-minute isotope ^{223}Fr , the alpha-decay daughter of 22-year ^{227}Ac , which is a decay product of ^{235}U found in natural uranium with an abundance only $\sim 0.7\%$. Although she did not win a Nobel Prize for this discovery, Perey was later (1962) elected as a corresponding member of the French Academy of Science, an honor which was never accorded Marie Curie. (However, in 1922 the French Academy of Medicine broke a long-standing tradition and *did elect Marie to be their first woman member* in recognition of her seminal role in the use of radium in cancer therapy).

Of course, as discussed earlier, most successful of all was daughter Irene Joliot-Curie who with husband Frederick Joliot-Curie shared the 1935 Nobel Prize in Chemistry for discovery of “artificial radioactivity”.

In closing, I should like to make some comments about the influence of the legacy of Marie Curie on women and their career choices. As early as the 1930s when I was in elementary school I read about Marie Curie and learned of her discoveries of the new elements polonium and radium. Sometime later I read Eve Curie’s biography of her mother published in 1937. I remember how impressed I was that Marie Curie married, worked in the laboratory with her husband, had two accomplished children, and after Pierre’s death managed to recover from the disaster, continue her research studies, run a laboratory and, in addition, find time to spend with her children and enjoy excursions to the countryside and seashore with them on a regular basis.

When I graduated from high school in 1944, it was still the policy in the United States that if a woman teacher married, she had to resign her teaching position, and because of this (even though my father was a school superintendent), I declared I would never become a teacher! The policy was somewhat relaxed during WW-II when it became necessary to allow a few married women to teach in order to staff the schools and universities, but after the war women were not supposed to continue in these positions formerly held by men. When I entered Iowa State College (now Iowa State University) in Ames, Iowa in 1944, I observed that all my female professors were older, unmarried women, “spinsters” or “old maids” as we used to call them. When I decided to change my major from Applied Art

to chemistry because of the *inspired* teaching of freshman chemistry by an older, unmarried woman, I was asked by my counselor (a spinster art professor) whether I thought that was a “respectable profession for a woman”. I said, of course, my chemistry professor is a woman!

However, I vowed to follow the Marie Curie model and marry and have children if I so chose, or to remain single, if I preferred – I felt the choice was entirely mine and that Marie Curie had demonstrated that it was possible either way! She had done it! Mdm. Curie had pursued her research with a husband and two children, but later on was able to continue her own pioneering research in radioactivity, founding the discipline of radiochemistry, winning another Nobel Prize, and directing her own laboratory. In addition, she raised two daughters and lived to see their subsequent successes. Irene followed in her mother’s footsteps by marrying a fellow scientist with whom she conducted collaborative research and won a Nobel Prize and produced two children. Younger daughter Eve chose an entirely different path. She was a successful concert pianist, author of her mother’s authoritative biography in 1937 (a best seller), a special war correspondent during WW-II for the Herald Tribune Syndicate, New York, and Allied Newspapers, Ltd., London. She later married Henry Labouisse who as Executive Director of UNICEF accepted the 1965 Nobel Peace Prize, yet another Nobel Prize winner in the family!

In my reading of various biographies of Marie Curie I became aware that she realized she couldn’t do everything all by herself and clearly understood the necessity for having additional help in her household. She enlisted the help of a nanny, maid, sometimes a cook, and Polish speaking governesses for the children. Pierre’s widowed father until his death added a steadying influence, especially for Irene. It is important for women to know that it is acceptable for them to engage outside paid help in order to spend “prime” time enjoying their families and be able to go on excursions, vacations, hiking, museum trips, or what ever they choose with their families and partners as desired, and to be careful to renew their own energy and health as did Mdm. Curie.

We are all, both men and women, beneficiaries of Marie Curie’s legacy, not only her world-changing research contributions, but her clear intent as Laboratory Director and ‘la Patronne’ to encourage and enable both women and men, and all nationalities equally, to excel in their endeavors, to treat them with respect and a nurturing atmosphere, and to furnish the best facilities possible; in return, she expected their best efforts and dedication to their science.

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3. IUPAC, vol. 33, no. 1, Marie Skłodowska-Curie, a special issue commemorating the 100th anniversary of her Nobel Prize in Chemistry (2011). [The news magazine of the International Union of Pure and Applied Chemistry

(IUPAC) just published this special issue. It is a superb compendium of authoritative articles celebrating not only Marie Skłodowska-Curie's scientific achievements, but also showing what an extraordinary and amazing person she was and the tremendous breadth of her interests and achievements. In addition to authoritative biographical sketches and articles on various aspects of Marie Curie's life and research, accounts of other relevant discoveries of the time, medicine after the discovery of radium, many

photos and references, and information about programs and institutions bearing her name are included. It is an invaluable resource.]

4. McGrayne Bertsch S (1998) Nobel Prize women in science: their lives, struggles, and momentous discoveries, 2nd ed. Carol Publishing Group, Secaucus, NJ
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