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THEY WERE THE FIRST: NOBEL PRIZE WINNERS MARIE CURIE AND IRÈNE JOLIOT-CURIE

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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
Marie Curie

This article aims to highlight the major milestones in the lives of two great women scientists who became icons for many women and girls empowering them in their search for a life path. A double Nobel Prize winner in two different fields (1903 and 1911) Marie Curie discovered new elements polonium and radium, isolated radium and studied its nature and compounds. Her daughter Irène Joliot-Curie, a 1935 Nobel Prize winner, synthesized new radioactive elements. Their scientific and civic activities expanded and deepened understanding of the physical world, made breakthroughs in medicine, and changed society's ideas on the role of women.

K e y w o r d s: women-scientists, women – Nobel Prize winners, the Nobel Prize, Marie Curie, polonium, radium, Irène Joliot-Curie, artificial radioactive elements.

Unfortunately, even today women face barriers to career advancement in science, not to mention receiving scientific awards, the most prestigious of which is the Nobel Prize. Between 1901 and 2025, the Nobel Prizes and the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel were awarded 633 times to 1 026 people and organizations. Given that some received the Nobel Prize more than once, this makes a total of 990 individuals and 28 organizations [1], of which only 68 are women [2]. In the scientific world, despite some positive changes, common belief that women are less competent in science because science is a "men's business", as well as everyday discrimination, such as underpayment, lack of scientific recognition and promotion, are still prevalent, sometimes under the guise of benevolent attitude. This challenge arose long ago, and it is clear that there is still a long road ahead. Not only the scientific community or the Nobel Committee, but the global society need to take a different look at the role of women in science, overcome subconscious bias, and pay tribute to those who rightfully deserve the highest recognition [3]. Today, there is increasing criticism of gender bias from representatives of the scientific community about the inertia of this community and the Nobel Committee in particular. As a New Zealand physicist L. Winkless put it, "if the committee had had their way, Marie Curie would not have received the 1903 physics prize" [4].

Nowadays, it is no secret that research carried out by women-scientists makes it possible to combine brightness of mind, deep knowledge with humaneness and wisdom. Their approaches to the problems and the ways to solve them are largely determined by their maps of meaning and existential experience that can enrich and expand the scientific field and, as a result, can offer unexpected but most

effective ways to solve the problems [5-8]. As a renowned computer scientist F.-F. Li put it, "you see the world in different ways: that's why your science can be unique" [9].

A striking example of such a female scientist is Marie Curie-Skłodowska, who became the first and most famous woman in the world to receive the Nobel Prize twice at the beginning of the 20th century, at a time when women were not even admitted to universities in many countries around the world. She also became a role model for many young women who dreamed of a scientific career and, first of all, for her daughter Irène, who continued the family tradition by becoming a Nobel laureate in 1935. This paper is aimed at revealing the major milestones in the lives of these two outstanding women.

Marie Curie. The Nobel Prize in Physics 1903. The Nobel Prize in Chemistry 1911

Marie Curie [10]

A Polish-born French physicist and chemist Marie Curie (née Maria Salomea Skłodowska) was born in Warsaw (then part of the Russian Empire) on November 7, 1867, in the family of teachers. Her father Vladislav Sklodowski taught math and physics and her mother Bronisława was a headmistress at a girl's school. Maria was the youngest of five children, and family members called her Manya [11]. Sklodowski family life under the Tsarist regime was not easy: as they were involved into struggle for Poland's independence [12], they had lost their property and fortunes, had faced financial hardships, and had moved to ever-smaller apartments. When the girl was eleven, her mother died of tuberculosis [13], after which Maria's life was never the same.

Growing up in the family of educators, young Manya was taught to read and write early and was fascinated by her father's laboratory equipment, which likely sparked her interest in science. At the age of ten, Maria began attending J. Sikorska's boarding school; her father also taught her. Then she attended a gymnasium for girls, from which she graduated in 1883 with a gold medal award [14]. Maria recalled her studies during this period: *"I easily learned mathematics and physics, as far as these sciences were covered in the school. In this I received ready help from my father who loved science. Unfortunately, he had no laboratory and could not perform experiments. My lonely studies were fraught with hardship. The education which I had received in middle school was of a much lower standard.... I tried to supplement it on my own, with books 1 had gathered. It was not a very effective method, however I fell into a routine of lonely study and later I discovered how useful what I had learned was"* [15].

After a collapse, due possibly depression, Maria spent the following year in recovery with relatives of her father out of Warsaw [12, 14]. Returning to Warsaw, Maria could not continue her formal learning because this wasn't something that young women did in Poland back then as universities were a "men's world" [16]. That's why she and her sister Bronisława became involved in the Flying University (sometimes translated as Floating University), a Polish patriotic institution of higher learning that admitted women students. The aim of the Flying University was to provide educational opportunities for Polish youth within the framework of traditional Polish scholarship, and among the lecturers were the best Polish academics. During the twenty years of its existence (1885–1905), the Flying University paved the way to the future for more than five thousand women and men. A group of active, patriotic young people, including Maria, emerged at the university. They believed that their country's hope lay in a major effort to develop the nations intellectual and moral strength. Their primary goal was to educate themselves while simultaneously providing educational facilities for workers and peasants: *"I have a clear remembrance of the sympathetic intellectual and social companionship which I enjoyed at that time. While the means of actions were poor and the results obtained were not considerable; yet I still believe that the ideas which inspired us then were the only way to bring about real social progress. You cannot hope to build a better world without*

improving individuals. To that end each of us must work for his own improvement, and at the same time share a general responsibility for all humanity. Our particular duty was to aid those whom we think can be most useful" [15].

Dreaming about further education, Maria thought of the Sorbonne University in France, in which women had a chance to study at that time. However, she did not have the money for it. Thus, she agreed to work to help pay for her sister Bronisława's education in France, if she would help Maria after she graduated. Bronisława Dłuska (*née* Skłodowska) became a physician and co-founder and first director of Warsaw's Maria Skłodowska-Curie Institute of Oncology [17]. For six years, Maria had worked as a governess and a tutor, studying in her spare time. In 1891, after Bronislawa's graduation, Maria moved to France to enter the Sorbonne. In order to fit in, she changed her name to Marie.

Marie's life in France was difficult; she earned not much money by tutoring and often suffered from hunger and cold exposure, however a young woman stated that her situation was not exceptional, because many of Polish students whom she knew were in in the same situation [19]. Being brilliant and well-prepared, young Marie was happy to study: "*It was like a new world opened to me, the world of science, which I was at last permitted to know in all liberty*" [13]. She studied physics, chemistry, and mathematics. In 1893, she was awarded a degree in physics and began her work in an industrial laboratory of Gabriel Lippmann. She received a scholarship to conduct a study on the magnetic properties of certain steels, and with the aid of a scholarship she earned a second degree in mathematics in 1894.

Looking for a new lab to carry out research in magnetism, Marie was introduced to an experienced physicist Pierre Curie known for his work on piezoelectricity, as well as his work on magnetism and symmetry in physics; and this meeting changed both their lives and science. Pierre Curie found Marie fascinating as a scientist, and eventually their relationship was grown from friendship into love. When Pierre proposed marriage, Marie did not accept the proposition as she was planning to return to Poland and to work in the chosen field; but she was denied a place at Kraków University because of sexism in academic field [20]. Pierre convinced her to return to France, and in 1895 they became wife and husband. Two daughters were born from this union – Irene in 1897 and Eve in 1904.

Family responsibilities did not distract Marie from her dreams of science and making the world a better place to live. Despite being married to a renowned physicist, Marie still wanted to become a teacher. In 1900, she started teaching physics at *École normale supérieure*, where she continued to teach until 1906 [18].

Meanwhile, in 1895, Wilhelm Roentgen discovered the existence of X-rays, though the mechanism behind their production was not yet understood, and in 1896, Henri Becquerel reported the discovery of radiation emitted by uranium salts. Influenced by these two important discoveries, Marie Curie decided to look into uranium rays as a possible field of research for a thesis. She used an apparatus developed by her husband in order to analyze and quantify these rays. Marie confirmed Becquerel's observations that the electrical effects of uranium rays are constant, regardless of its state or expose to heat or light. Marie confirmed Becquerel's conclusions that minerals with higher uranium content emitted the most intense rays. She further elaborated Becquerel's ideas developing the hypothesis that radiation was not the outcome of some interaction of molecules but must come from the atom itself [21]. It was a huge step ahead because atoms considered to be indivisible (hence their name, dating back to the times of Leucippus and Democritus). These early discoveries opened the doors to an amazing and previously incomprehensible microworld.

Intrigued by the results his wife obtained, Pierre Curie abandoned his own research on crystals to work alongside Marie, "Marie tested all the known elements in order to determine if other elements or minerals would make air conduct electricity better, or if uranium alone could do this. In this task she was assisted by a number of chemists who donated a variety of mineral samples, including some containing very rare elements. In April 1898 her research revealed that thorium compounds, like those of uranium, emit Becquerel rays. Again, the emission appeared to be an atomic property" [21]. Marie Curie coined the term "radioactivity" to describe the behavior of uranium and thorium.

Marie understood the importance of publishing her discoveries in a timely manner and thus prioritizing her work. The research idea belongs to her; no one helped her formulate it, and although she turned to her husband's opinion, she clearly established her ownership of it: "She later recorded the fact twice in her biography of her husband to ensure

there was no chance whatever of any ambiguity. It [is] likely that already at this early stage of her career [she] realized that... many scientists would find it difficult to believe that a woman could be capable of the original work in which she was involved" [22]. She was aware of sexism in the academy very well.

In 1898, her paper was presented by Prof. Lippmann, however, G. C. Schmidt was two months ahead of Marie when he published his research in Berlin [22]. This did not stop Marie, since her article already contained the seeds of future discoveries. In collaboration with her husband, Marie Curie investigated pitchblende, a uranium-rich mineral found in abundance in Central Europe [23]. Their efforts led to the discovery of the first radioactive element, which was named "*polonium*" in honor of Marie's motherland Poland divided by Russia, Austria and Germany. In July 1898, the couple published a joint paper polonium, and in December 1898 they announced the existence of a second element, which they named "*radium*" (derived from Modern Latin radius (ray) [24].

To convince scientific community, Marie and Pierre Curie sought to isolate polonium and radium in pure form. Despite the industrial assistance of the Central Chemical Products Company the Curies received, it took Marie over three years to isolate one tenth of a gram of pure radium chloride. As for polonium, she never succeeded in isolating it, because it has a half-life of only 138 days [21]. Following these discoveries, they continued their study of radioactivity. To facilitate their chemical work, Pierre and Marie were granted the use of a hangar in the courtyard of EMPCI. Through their tireless work, the Curies were eventually able to produce one decigram of pure radium in 1902. This enabled them to measure the atomic weight of radium and thus identify the position of this element in the Periodic Table [25]. Between 1898 and 1902, the Curies published, jointly or separately, a total of 32 scientific papers. At the First International Physics Conference in 1900, the Curies showed that a material containing radium spontaneously emitted light. The fact that radioactive phenomena are caused by processes within the atom sparked intense interest within the scientific community.

In June 1903, Marie Curie was awarded her doctorate from the University of Paris. That month Marie and Pierre were invited to the Royal Institution in London to give a speech on radioactivity [26]. However, Marie as a woman was prevented from speaking, and Pierre alone was allowed to [27].

Marie and Pierre Curie in their laboratory in Paris [25]

The Curies published in detail all the processes they used to isolate radium, without patenting any of them. Marie Curie put it this way: "*Radium need not make anyone rich. It is an element, it belongs to everyone*" [25]. But a thriving industry soon emerged based on their discoveries. Their work with radium demonstrated its tissue-damaging properties, laying the foundation for the fight against cancer and other diseases. The couple began collaborating with the French industrialist Armet de Lisle, which furthered their scientific research. However, the couple benefited little from this increasingly profitable business.

Despite strong sexism in academic circles, Marie Curie's achievements were recognized by the scientific community, although not everything was smooth sailing. In December 1903, the Royal Swedish Academy of Sciences awarded Pierre Curie, Marie Curie and Henri Becquerel the Nobel Prize in Physics. At first, the intention of the committee was to honor Pierre Curie and Henri Becquerel. However, a highly influential Swedish mathematician Magnus Gösta Mittag-Leffler alerted Pierre Curie to the situation, and after Pierre's complaint, Marie's name was added to the nomination [27]. Marie Curie became the first woman to be awarded a Nobel Prize.

The Nobel Prize in Physics 1903 was divided, one half awarded to Antoine Henri Becquerel "*in*

recognition of the extraordinary services he has rendered by his discovery of spontaneous radioactivity", the other half jointly to Pierre Curie and Marie Curie, née Skłodowska "*in recognition of the extraordinary services they have rendered by their joint researches on the radiation phenomena discovered by Professor Henri Becquerel*" [28].

Marie and Pierre Curie did not receive the prize in person; but as Nobel laureates were required to deliver a lecture, they undertook the trip in 1905 [27]. In his presentation speech, President of the Royal Swedish Academy of Sciences Dr. H. R. Törnebladh, addressing the French government representative, who received the prize in the Curies' absence, declared: "The great success of Professor and Madame Curie is the best illustration of the old proverb, coninucta valent, union is strength. This makes us look at God's word in an entirely new light: "It is not good that the man should be alone; I will make him an help meet for him". Nor is that all. This learned couple represent a team of differing nationalities, a happy omen for mankind joining forces in the development of science. With sincere regret that these two prize-winners are prevented by commitments from being with us, we are fortunate in having in their stead the distinguished Minister, M. Marchand, representing France who has most kindly consented to receive the prize awarded to his fellow-countrymen" [29].

The award money allowed the couple to hire their first laboratory assistant. After receiving the Nobel Prize, Pierre Curie, who previously could not find a place in French universities, got an offer from the University of Geneva. And France immediately "recalled" her glorious son, and the University of Paris gave him a professorship and the chair of physics, although the Curies still did not have a proper laboratory [30]. Becoming a Titular Professor of Physics at the Sorbonne Faculty of Sciences, Pierre acquired the opportunity to get a small laboratory; however, it was not ready until 1906. In November 1904, Marie Curie became a Chief of the laboratory [25]. In 1905, Pierre was elected to the French Academy of Sciences.

It seemed that life smiled at the Curies. They went okey, but soon tragedy struck. At the age of 46, Pierre Curie died suddenly from a street accident in Paris. Despite the terrible blow of fate, Marie moved forward: "*Crushed by the blow, I did not feel able to face the future. I could not forget, however, what my husband used to say, that even deprived of him, I ought to continue my work*" [31]. She continued the research on which they had been working together, and raised their two daughters. The Department of Physics of the University of Paris decided to retain the chair that had been created for her late husband and offered the chair of Pierre to Marie, which she accepted. Marie was dreaming of creating a world-class laboratory as a tribute to her husband. *Marie Curie became the first woman-professor at the University of Paris.*

Curie's idea to create a new laboratory did not end with the University of Paris. With the help of friends, left-wing politicians, and a substantial grant, Marie managed to secure funding for a new Radium Institute. Marie Curie was to head one of its divisions, the radioactivity laboratory, while an eminent physician would supervise the second division, a medical research laboratory.

Marie began her laboratory research to confirm that radium was not a compound of lead and five helium atoms, as Lord Kelvin claimed, but an element which deserved to be in the Periodic Table. It took years, but the measurements left no doubt. Marie isolated radium metal and published her comprehensive textbook "Traité de radioactivité" (A Treatise on Radioactivity) [32]. Marie Curie secured the right to define an international standard for radium emissions. The measure she established was accepted by the international scientific community, which named it the Curie.

However, despite such achievements, Marie's life was not a bed of roses. Scandal erupted when she offered herself as a candidate for the single vacant seat (physics) in the French Academy of Sciences. Her only competitor was a physicist Edouard Branly, who pioneered the development of radio waves and transmission. "Socially, Branly had many more attractive features to his candidacy. In this Catholic nation, he was devoutly religious and the physics professor at the Catholic University in Paris; Curie was too busy in her lab to sit in church. Branly was also well-regarded as a family man who lived his life on a solid moral high ground – a direct slam on Curie's personal life decisions. Branly even knew the pope" [33]. The right-wing press began to hound Marie accusing her of being not truly French, atheist, etc. and thus undeserving of a seat in the French Academy. Although the liberal press came to her defense, the accusations damaged her image [34]. She lost the seat because, as Howard Markel put it, "in 1911, it must be recalled, academia was a highly structured patriarchy and old boys' club" [33].

An even worse scandal erupted over her relationship with a fellow physicist Paul Langevin. An endless series of undeserved insults and suspicions began to terrorize Marie. Upon returning from a conference held in Belgium, Marie met an angry mob congregated in front of her home. Marie and her daughters had to take refuge in the home of friends in Paris, while Paul Langevin and a journalist who had reviled Curie held a duel – an emotional but bloodless "affair of honor" [35]. All this undermined Marie's physical health and psychological state.

In 1911, Marie Curie got, so to speak, satisfaction, having proven to the French Academy and French society her value as a researcher and pioneer in science – she had been given a second Nobel Prize, this time in chemistry. Although deeply shaken by the scandals surrounding her, she found the strength to attend the Nobel ceremony. The Nobel Prize in Chemistry 1911 was awarded to Marie Curie, née Skłodowska "*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*" [36].

1911 Nobel Prize diploma [37]

Marie Curie was the first woman to win a Nobel Prize, the first person to win a Nobel Prize twice, and the only person to win a Nobel Prize in two different scientific fields. And if evil tongues could say that Marie Curie owed her first prize to her husband, then the second prize she received refuted not only this statement, but the very concept of the incompetence of women in science.

The re-recognition by the Nobel Committee enabled Marie Curie to persuade the French government to support the Radium Institute built in 1914, in which research was conducted in chemistry, physics, and medicine. Later, she headed the Radium Institute (Institut du radium, now Curie Institute, Institut Curie) [38].

Marie's activities extended beyond the scientific community; and during the First World War she quickly understood that soldiers needed to carry out operations as soon as possible. She realized that field radiology centers on the front lines were essential for surgeons, including to prevent amputations if limbs could be saved. Therefore, Marie Curie developed mobile radiography units, which became widely known as "petites Curies" (little Curies) [39]. Marie Curie became the director of the Red Cross Radioloy Service and set up France's first military radiology center. One of her assistants was her 17-year-old daughter Irène. Marie also produced hollow needles containing "radium emanation" (late identified as radon) to sterilize infected tissue. It is estimated that over a million wounded soldiers were treated with her X-ray units [22]. After the war, she summarized her wartime experiences in her book "La Radiologie et La Guerre" (Radiology in War) [40].

In 1920, the French government established a scholarship for Marie Curie. In 1921, Marie toured the United States to raise funds for radium research, where she was greeted with triumph [41]. In 1922, she became a fellow of the French Academy of Medicine. Thanks to her dedicated efforts, the Radium Institute became one of the four largest laboratories in the world for radioactivity research. In 1922, Marie Curie became a member of the League of Nations' newly created International Committee on Intellectual Cooperation, where she served until 1934. In 1925, she visited Poland to attend the foundation-laying ceremony of the Warsaw's Radium Institute, and in 1929, she visited the United States again and equipped the Warsaw Radium Institute with radium [42]. In 1930, she was elected to the International Committee on Atomic Weights, where she served until her death [43].

Marie Curie's work with radioactive substances could not have gone unnoticed for her health. On 4 July 1934, she died aged 66 at the Sancellemoz sanatorium in Passy, Haute-Savoie, from aplastic anemia believed to have been contracted from her long-term exposure to radiation, causing damage to her bone marrow [44]. She was interred at the cemetery in Sceaux, alongside her husband Pierre. In 1995, in honor of their achievements, the remains of both were transferred to the Paris Panthéon. Their remains were sealed in a lead lining because of the radioactivity [45].

The activities of the Curies, and Marie Curie in particular, have shaped the world around us. In the scientific field, Marie helped challenge established ideas in physics and chemistry. In medicine, "her pioneering work demonstrated that radiation is a powerful tool with a wide range of potential applications, which include a range of diagnostic and therapeutic medical procedures. Marie Curie has left a great deal to the world. Her work led to the development of nuclear energy and radiotherapy (RT) for the treatment of cancer" [46]. Marie is called the mother of radiotherapy whose light still guides cancer medicine [47]. S. Weart emphasizes that "all medicine that relies on radioactivity – on irradiating people – goes back to Marie Curie" [48]. In terms of social issues, Marie had to overcome gender barriers and sexism in both her home and adoptive countries and helped other women achieve success in science (at least 45 women passed through her lab) [49], which makes her a forerunner of feminism and an icon in the world of modern science for all women and girls.

As Marie Curie put it, "*I am among those who think that science has great beauty. A scientist in his laboratory is not only a technician, he is also a child placed before natural phenomenon, which impress him like a fairy tale*" [50].

Irène Joliot-Curie. The Nobel Prize in Chemistry 1935

Irène Joliot-Curie [51]

A French chemist, physicist, and politician **Irène Joliot-Curie** was the elder daughter of Pierre and Marie Skłodowska-Curie and the wife of Frederic Joliot-Curie, with whom she collaborated on natural and artificial radioactivity, transmutation of elements, and nuclear physics [52]. She was born in Paris, France, on September 12, 1897. She grew up in the scientific environment saturated with scientific inquiry and new ideas. Her parents were very busy, and a girl spent time with her paternal grandfather, a retired doctor who taught her to love nature, poetry, and radical politics [51].

Marie, Pierre and Irène Curie [53]

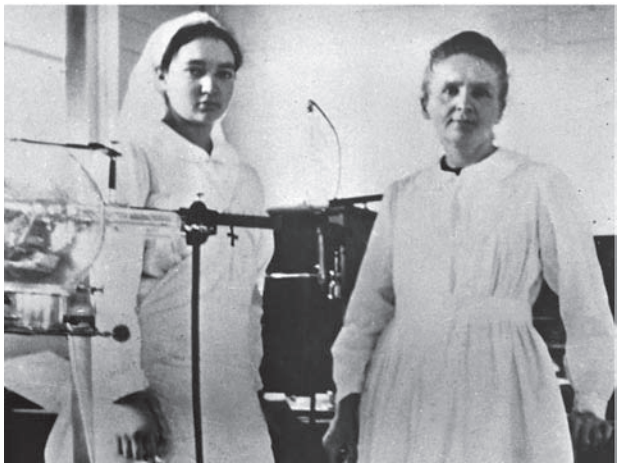
Education was important in the Curie family. and Irène's education began at six when she entered school. Irène was very intelligent and had exceptional talent in math [54]. In 1906, tragedy happened – Marie Curie lost her husband and Irène and her younger sister Eve – their father. Marie was left alone to raise daughters, for whom she wanted a bright future. Irène got an unusual experience of attending a special school that emphasized science, organized by her mother Marie and Marie's friends/colleagues [55]. The curriculum was varied and included the principles of science and scientific research, as well as Chinese and sculpture, and with great emphasis placed on self-expression and play. Irène studied in this environment for about two years [56]. Then the girl returned to a more orthodox learning environment by going back to high school at the Collège Sévigné and studied there until 1914 when she entered the Sorbonne to prepare for a baccalaureate in math and physics. However, her education was interrupted by the First World War; and young Irène left the university to assist her mother with mobile x-ray facilities that helped to save the so many lives. She also oversaw the development of X-ray equipment in military hospitals in France and Belgium. After the war, she was awarded the War Medal for these services [54].

After the war, Irène restarted her studies. She agreed on the position of the laboratory technician in the Radium Institute in Paris, and, while working toward her doctorate, she became her mother's assistant. By 1921, Irène had already earned a bachelor's degree in physics and mathematics. She was interested in radioactivity and developed equipment for measuring the radioactivity of substances used in agriculture. She also began researching the alpha particles emitted by polonium. Irène included the results of this research in her doctoral thesis, which she defended in 1925 [58]. Marie Curie asked her to train a physics and chemical engineer Frédéric Joliot. During their collaboration, Irène and Frédéric understood that they could be good partners both in work and life; and they married in 1926 [51]. Like Irène's parents, they decided to conduct research jointly and took the name "Joliot-Curie".

Spouses began their research, which led to brilliant scientific discoveries. Unfortunately, misinterpreting their measurement results, they were overtaken on the path to fame and recognition by James Chadwick, who proved the existence of neutron, and Carl David Anderson, who proved the existence of positron. Between 1932 and 1934, they jointly published a number of important papers on the effects of alpha particles on various elements and conducted nuclear transmutation reactions, which led to the discovery of artificial radioactive elements [58]. Frédéric Joliot-Curie put it this way: "*With the neutron we were too late. With the positron we were too late. Now we are in time*" [59].

The results of their extended experiments demonstrated a causal mechanism of artificial radioactivity: alpha-induced neutron emission creates neutron-rich or proton-rich nuclei unstable to beta decay, independent of spontaneous natural processes [60]. The couple reported their findings in Comptes Rendus de l'Académie des Sciences on January 15, 1934, detailing the physical and chemical evidence [61]. The ability to artificially create radioactive atoms changed the course of modern physics. This groundbreaking work earned Frédéric and Irène Joliot-Curie the Nobel Prize in Chemistry. In 1935, it was awarded jointly to Frédéric Joliot and Irène Joliot-Curie "*in recognition of their synthesis of new radioactive elements*" [62].

The Joliot-Curie couple's time of triumph was overshadowed by the death of Marie Curie. Irène had to take over mother's responsibilities. Besides, by this time, the couple were parents of a daughter



Marie Curie and Irène Curie (left) operated the "petites Curies" and elaborated a program to train other women to use the X-ray equipment [57]

Hélène and son Pierre, who would one day be physicists like their parents and grandparents. In 1936, Irène Joliot-Curie was appointed Undersecretary of State for Scientific Research. In 1937, Irène was appointed professor in the Faculty of Science at the University of Paris. She was a member of several foreign academies and of numerous scientific societies, had honorary doctor's degrees of several universities, and was an Officer of the Legion of Honor [64]. Frédéric received a professorship at the Collège de France in 1937; he was elected to the Académie des Sciences in 1943, and became a foreign member of the Royal Society in 1946 [65].

Irène Joliot-Curie co-created the French Atomic Energy Commission in 1945 and held a six-year term, while promoting nuclear research and development of the first nuclear reactor. She later became director of the Curie Laboratory at the Radium Institute.

Joliot-Curie's discoveries paved the way for the widespread use of radioisotopes in medicine: "today, radioactive iodine is used regularly to treat thyroid diseases. Radioisotopes that emit positrons – the positive equivalent of the electron – are used in medical PET scans to image and diagnose cancer, and others are used for cancer therapy" [66].

In addition to her very active scientific work, Irène Joliot-Curie was also involved in civic life. As a member of the Comité National de l'Union des Femmes Françaises and of the World Peace Council she spoke against fascism and Nazism. She fought for equal rights for women. In 1939, fearful of how the military might use her research in nuclear fission,

The 1935 Nobel Laureates at the Nobel Prize Award Ceremony in the Golden Hall of the Stockholm City Hall, 10 December 1935. From left: James Chadwick, Irène Juliot-Curie, Frédéric Joliot and Hans Spemann [63]

she and her husband locked their documentation in a vault [51]. The Joliot-Curies were deeply concerned about the potential harm, as well as the benefits, of using atomic energy. In his Nobel lecture, Frédéric Joliot-Curie warned: "If such transmutations do succeed in spreading in matter, the enormous liberation of usable energy can be imagined. But, unfortunately, if the contagion spreads to all the elements of our planet, the consequences of unloosing such a cataclysm can only be viewed with apprehension" [67]. These ideas subsequently became central to peace activities of a double Nobel Prize winner L. Pauling [68]. Indeed, radioactivity can save lives, but it can also kill. Like her mother Marie Curie before her, and then her husband just two years later, Irène Joliot-Curie died of leukemia caused by extensive radiation exposure in 1956. "Like many visionaries, she paid a high price for being decades ahead of the rest of the world" [69].

Life journey of two great women – Marie Curie and Irène Joliot-Curie – is a way of self-discovery and self-development, in which the various aspects of their personalities come together to create unique integrity. To fully realize the potential of women in science and society, it is necessary to "dismantle the systems that maintain inequities, as well as to raise up and empower women of all ages, colors, abilities to assert themselves and be respected in all spheres, to do wonders for everyone on our planet, and to know that every woman matters" [70].

ВОНИ БУЛИ ПЕРШИМИ: ЛАУРЕАТКИ НОБЕЛІВСЬКОЇ ПРЕМІЇ МАРІЯ КЮРІ ТА ІРЕН ЖОЛІО-КЮРІ

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У статті висвітлено основні віхи життя двох видатних жінок-науковиць, які стали іконами для багатьох жінок та дівчат, надаючи їм сили у пошуках життєвого шляху. Марія Кюрі, двічі лауреатка Нобелівської премії в різних галузях (1903 та 1911 роки), відкрила нові елементи – полоній і радій, виділила радій і дослідила його природу та сполуки. Її донька Ірен Жоліо-Кюрі, лауреатка Нобелівської премії 1935 року, синтезувала нові радіоактивні елементи. Їхня наукова та громадська діяльність розширила та поглибила розуміння фізичного світу, здійснила прориви в медицині та змінила уявлення суспільства про роль жінок.

Ключові слова: жінки-вчені, жінки – лауреати Нобелівської премії, Нобелівська премія, Марія Кюрі, полоній, радій, Ірен Жоліо-Кюрі, штучні радіоактивні елементи.

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