Luigi Dei

Maria Skłodowska Curie

The obstinate self-sacrifice of a genius

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Preface

Luigi Dei takes a very personal approach to presenting the life and achievements of Maria Skłodowska-Curie, saetting them in the broader context of the history of science and European culture between the nineteenth and twentieth centuries. More specifically, he traces the links of the scientist, who twice won the Nobel Prize, with Poland (her homeland) and France (the country in which she lived, worked and made her outstanding scientific discoveries).

Marie Curie also had close bonds with several other countries. England, for example, where she spent several months with her friend Hertha Ayrton in 1912, and where Ernest Rutherford lived, a fellow scientist with whom she collaborated and enjoyed an exchange of views on scientific matters of mutual interest. She also

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had relations with the United States, which she visited twice in 1921 and 1929 to raise funds for the Radium Institutes in Paris and Warsaw. In 1925 Marie also visited Czechoslovakia, invited by the President and the local scientists: the deposits of raw uranium from which she extracted radioactive elements were located in this country.

Italy is rarely mentioned, largely because we know very little about the contacts Marie had with this country. Nevertheless, some information is to be found in her auto-biography, where she wrote: "Following the failure of the German attack, in the summer of 1918 I visited Italy at the invitation of the government to study the deposits of radio-active minerals. I spent a month there, with a certain success since I managed to convince the local authorities of the importance of this new subject".[1]

Although this was her first trip to Italy, Marie Curie was a figure already known to the Ital-

[1] M. Skłodowska-Curie, *Autobiografia*, in: M. Skłodowska-Curie, *Autobiografia* i *Wspomnienia o Piotrze Curie*, Warszawa 2004, p. 45.

ians. After the Nobel Prize of 1903 she and her husband obtained many other recognitions. In 1904 the Società Italiana delle Scienze awarded them the 'Matteucci' Medal, and the discovery of the radioactive elements was mentioned in various publications by Italian scientists. In 1909 Marie Curie became a corresponding member of the Accademia delle Scienze in Bologna. In the same year, the Società Italiana per il Progresso delle Scienze invited her to hold a conference in Italy, but she was forced to decline the invitation in view of the intensive research activity in which she was engaged.

Information regarding the visit to Italy made by Maria Skłodowska-Curie in August 1918 has been provided by Bronisław Biliński, a tireless scholar of the contacts between Italy and Poland, who died in 1996. In the 1960s Biliński was able to talk to people who had known Marie Curie in Italy, in particular Camillo Porlezza, who accompanied the scientist throughout her stay. Biliński also visited the private archive of Professor Vito Volterra, senator and director of the Ufficio Invenzioni e Ricerche, who acted as a go-between with the government to secure Marie Curie's invitation to Italy.

At the time, preliminary research was being carried out in Italy on the radioactive substances present in nature: in stones, mineral water, gases etc. The problem was finding a way of extracting them and exploiting them for practical purposes. The purpose of Marie's visit was to confirm what the Italian scientists had established so far and to identify new sources of radioactive elements, as well as defining methods for extracting and exploiting them.

Marie arrived in Pisa, where she met Camillo Porlezza, who was an official in the Military Engineers Corps at the time, the War not yet being over. She came on her own, and at Pisa station at three o'clock in the morning there was only Porlezza to meet her. His impression was of a slender, ascetic woman who was, at the same time, strong and unyielding in carrying forward the enterprises she undertook.

Marie stayed in Italy for almost three weeks, from 30 July to 18 August. As well as Pisa and the surrounding area she also visited Larderello, Bagni San Giuliano and Montecatini. From there she headed south, towards Napoli, Ischia and Capri, and then headed north again, to Abano, Montegrotto and Battaglia and as far as Lurisi in Piemonte. Her journey ended in San Remo, where she had a meeting to talk about the research performed, and presented a report to the authorities. The document is divided into three sections, dealing respectively with scientific, practical and administrative aspects.

The scientific mission of Maria Skłodowska--Curie did not end with this report. It also had a practical and organizational significance in that it had a decisive influence on the creation of the Commissione Nazionale Italiana per le Sostanze Radioattive, established in 1919. In a document drafted by Vito Volterra and addressed to Marie Curie, the Italian National Committee indeed thanked her for the major contribution she had made to the research into the Italian sources and deposits of radioactive substances, as well as for her suggestions regarding the research. The document also expressed the hope of collaboration with the Laboratorium Curie and the Commission Française du Radium, in which Marie held a position of the utmost prominence. In that same year of 1918, Marie's laboratory was visited by Porlezza, Volterra and Raffaello Nasini, the scientists who had accompanied her during her journey through Italy. The Italian scientists also visited the establishments in which radioactive preparations were produced. The following year Marie Curie sent Porlezza the quantity of radiferous substances required to carry forward the experiments in Italy.

Marie Curie returned to Italy again in 1931 to attend the International Nuclear Physics Conference, organised in Rome from 11 to 18 October by the Reale Accademia d'Italia. It was attended by the greatest physicists of the time, including Niels Bohr and Enrico Fermi.

Maria Skłodowska-Curie visited many countries, demonstrating that she and her work were a heritage that did not belong only to Poland and France but surpassed national boundaries, bringing knowledge and assistance to both scientists and the public institutions established for the practical utilisation of scientific discoveries. An excellent example of this approach is Marie's journey through Italy in 1918 and its scientific and practical consequences.

Luigi
DEI

Maria Skłodowska Curie: the obstinate self-sacrifice of a genius

Numerous attempts have been made to define exactly what genius is, summing it up in a few well-chosen and memorable words: "Genius does what it must, and Talent does what it can" (Owen Meredith), "Genius might be described as a supreme capacity for getting its possessors into trouble of all kinds" (Samuel Butler), or "Genius is nothing but a great aptitude for patience" (Georges-Louis Leclerc, Comte de Buffon), or finally "A man of genius makes no mistakes; his errors are volitional and are the portals of discovery" (James Joyce). All these definitions can be applied to Maria Skłodowska-Curie, but the one I think is most apt for her is that of the French scientist Georges-Louis Leclerc: "a great aptitude for patience" which reveals to us the "beauty of her obstinate self-sacrifice". These last words

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were pronounced by the Nobel laureate Pierre Gilles de Gennes at the ceremony marking the transferral of Maria's remains to the Pantheon. And it is precisely this "obstinate self-sacrifice" of the genius that emerges as a leitmotif running through the intriguing adventure of her intense, tortured and extra-ordinary life.

Maria was born in Warsaw on 7 November 1867 in Poland under the repressive yoke of the Tsarist regime. The Austrian Empire had just become the Austro-Hungarian Empire; Italy had been unified for just six years and Florence was its capital. The Bolzano-Innsbruck stretch of the Brenner Railway, entirely within Austrian territory, had just been opened. In what would appear to be a sign of fate, Alfred Nobel invented dynamite in the year Maria was born: the fifth child of Władysław and Bronisława Skłodowski would become the first person to win the prize set up by the Swedish inventor not once but twice. 1867 was also the year in which Luigi Pirandello, Arturo Toscanini, the architect Frank Lloyd Wright and the painter François Xavier Roussel were born, and in which Charles Baudelaire and Michael Faraday died. And we can even fondly surmise that

Faraday –another outstanding scientist in the fields of both chemistry and physics – may have identified Maria, born three and a half months after he died, as the person best suited to carry on his work. In the same year Marx published *Das Kapital*, Tolstoy was writing *War and Peace* and Wagner the *Ring* tetralogy. Ibsen's *Peer Gynt* and Verdi's *Don Carlo* were performed for the first time. In Paris the *bande à Manet* was gaining strength, its exponents being not only Édouard Manet himself, Zola, Degas and Mallarmé, but also Cézanne, Pissarro and Renoir.

The population of Italy at the time was around 26 million. 75% were illiterate, and only 40,000 citizens had completed secondary school (now half a million Italians finish secondary school every year). In the 19 universities the number of students was around 9,000, and in the entire country there were 300 university lecturers in scientific subjects, 90 of them chemists. Nine months before Maria was born there were elections in Italy: only half a million Italian citizens had the right to vote, and only around 50% of these turned up at the polling station. And this was the situation more or less throughout the continent, although possibly not so dramatic everywhere. Perhaps these figures give us a better idea that any historical treatise of the world that Maria was going to have to address.

Maria, nicknamed Mania, was the fifth child of Włady-sław and Bronia; she had three sisters and a brother: the birth rate was very high at the time, almost a baby every year. Mania had a difficult childhood from the start. When she was four years old her mother contracted tuberculosis and had to spend long periods taking the cure in mountain resorts. Her father, who was a teacher at the Russian gymnasium, had difficulty making ends meet, but despite this he managed to instil in his children a love for their homeland and an aversion to the Tsarist regime, sacrificing himself so that they could study. When Maria was seven years old she lost her sister Zosia, who died of typhus. Helena too fell ill, but finally recovered after much suffering and a lengthy convalescence. Maria had hardly time to get over these tragic events before she found herself having to face another terrible loss. She was not even eleven years old when her mother died of tuberculosis in May 1878. Four years later the German doctor

Robert Koch isolated the causative agent of tuberculosis, which later became known as Koch's bacillus. In 1905 he won the Nobel Prize in Physiology and Medicine. All the Skłodowski children were good students who finished school with excellent marks. Maria took her diploma at the age of 15 from the government school in Warsaw, receiving a gold medal as the best female student of 1883. In this same year the engineer Karl Benz founded in Mannheim the automobile manufacturing company Benz & Company.

Maria then had to face several hard years studying and working as a governess for a wealthy family 80 kilometres from Warsaw. She also experienced sentimental afflictions and moods of depression brought on by an impossible love affair with the son of her employers, who was forced to break off their relationship for class reasons. Maria's strength of character, the patience and obstinate self-sacrifice mentioned above, began to emerge. As she confessed in a letter: "I have been through some very hard times and the only thing that alleviates the memory of them is that, in spite of everything, I have come through honestly and with my head held high."[1] More emphatically she also wrote, "First principle: never to let oneself be beaten down by persons or by events."[2]

In the meantime her sister Bronia had succeeded in gaining admission to the Sorbonne in Paris to study medicine; later she married Kazimierz Dłuski, a Polish emigrant who had been exiled for his radical socialist ideas. Bronia and her husband lived in Paris, the city Maria had dreamt of for years, and it was they who, in 1891, finally convinced her to join them there and try to get a place at the Sorbonne to study science. At the end of November of that year, just a few weeks after her twenty-fourth birthday, Maria left Warsaw with food, water, a stool and a fourth-class ticket on the cheapest train to Paris: 1,600 kilometres to be travelled in little more than three days. Maria got off at the Gare

[1] *Korespondencja polska Marii Skłodowskiej--Curie 1881-1934*, ed. by K. Kabzińska, Warszawa 1994, pp. 17-18.

[2] B. Goldsmith, *Obsessive Genius: The Inner World of Marie Curie*, New York 2005, p. 44.

du Nord, where her sister and brother-in-law were waiting for her. Sexual discrimination, poverty, possibly poor grounding in chemistry and physics were no hurdles in the face of this girl's persistence. For her spirit of adventure, her extraordinary intellectual curiosity and her unbridled thirst for knowledge the Sorbonne appeared a worthy testing-ground as well as a richly laden table.

Therefore we can say that Maria's scientific adventure truly began in 1891. In dark laboratories the great scientific discoveries which were to revolutionise physics and chemistry in the 19th and the first half of the 20th centuries were slowly germinating through the experiments of Crookes, Goldstein and Geissler. In the meantime, on the one hand Maxwell achieved the extraordinary mathematisation of all the phenomenologies connected with electromagnetism, mostly discovered by Faraday. On the other hand, there was an incredible growth in what we could now call operations of technology transfer. Thomas Alva Edison is perhaps the figure who best represents the excitement of these developments. He succeeded in producing electric filament bulbs that were sufficiently long-lasting to be commercially viable. In 1891 he also built the Kinetoscope, a device with a peep-hole viewer installed at the top of a large cabinet where people could watch short films for a penny. The most remarkable thing is that Edison was apparently not greatly interested in this device, which was the forerunner of the Kinetograph. For him the importance of the kinetoscope was primarily linked to his desperate quest to find a way of getting people to listen to music using his phonograph. His ingenious invention was equipped with earphones, so that people could put some loose change into the device and then watch the film accompanied by music. Later in the same year, Edison took out a patent on the radio. Can we define this extraordinary inventor as a genius too? I truly believe that we can, even though – as he himself admitted with great humility and modesty in one of his famous aphorisms – the notion of genius that fits him best is "one percent inspiration, ninety-nine percent perspiration". But let's get back to Maria, who is slowly transforming herself into Marie. The story of the next dozen or so years that I am going to tell you is nothing short of amazing.

The first years in Paris were harsh and exacting. Six months after her arrival Marie decided to go to live on her own, and for the next two and a half years she rented tiny apartments in the Latin Quarter. Here she lived in conditions of great hardship, especially on account of the cold, and she had to study night and day to make up the basic scientific knowledge required to enrol as a university student. Of the two thousand science students at the Sorbonne only twenty-three were women and two hundred and ten in the entire university out of a total of around nine thousand. This was the condition of women in *fin de siècle* France. Just to give an idea of the calibre of the teachers Marie would encounter each morning in the lecture hall, here are a few names: Paul Appell teaching courses on rational mechanics, Gabriel Lippmann who went on to win the Nobel Prize in Physics for the important contributions made to the development of colour photography, and the brilliant mathematician Henri Poincaré. All this was happening at a time when the pamphlet by Paul Julius Möbius on the *Physiological Feeble-Mindedness of Woman* was enjoying vast popularity and creating a great sensation, but not scandal, and the famous critic Gustave Planche had no qualms about declaring that “the role of women is linked simply to sex and reproduction”. However, almost in defiance of all this, Marie passed her *licence* examination in physics, coming first in the class, and in the following year passed the same level exam in maths, coming second and reproaching herself for this failure at a time when only five women had managed to achieve this qualification in that year.

The *étudiante étrangère* triumphed in the temple of culture and science, an *étudiante* – a term tellingly also used by the French at the time to signify the lover of a male student at the Sorbonne. Intellectually gifted women were portrayed as masculine, ugly and ungracious and, despite being industrious, were deemed incapable of making any significant contribution. At the utmost they would be seen as the invisible assistants of their male counterparts, who would always be hierarchically much superior. An ambiguous morality pervades the literature of the period: the celebration of male conquest in which the man’s mistress – preferably attractive and finely decked out –

increased his prestige, went hand in hand with the stigmatisation and condemnation of the 'fallen woman'. Adultery was conceded only to women of the upper classes, and on condition that it was discreetly concealed; when publicly revealed it was harshly censured. Although it was conceived and written in 1856, Flaubert's literary masterpiece *Madame Bovary* offers a perfect reflection of this situation, and even gave rise to a current of thought known as Bovarism which projected the concept far beyond the confines of the situation of women. Not to mention *Anna Karenina*, published in instalments between 1875 and 1877, which held the mirror up to an entire evolving society and its social conventions, traditions, upheavals and changing mores. Tolstoy's famous novel explored the tangled sentiments of hypocrisy, jealousy, faith, fidelity, carnal desire and passion caught up in the travails of the changes that were to characterise the decades to come in terms of the role of the family, marriage, society and progress, all revolving around the quartet of the protagonists: Anna-Vronsky, Levin-Kitty.

And so, with her second degree in mathematics, Marie laid the foundations for her extraordinary ascent of the sheer cliff face of female emancipation. After these two outstanding university achievements, in July 1894 Marie returned to Poland, and her father Władysław hoped that the Parisian adventure was concluded and that his daughter would begin her teaching career in her homeland. Marie herself did not seem averse to the idea. However, in the previous spring she had met a man, a physicist eight years her senior. Although very self-effacing, he was a brilliant scientist, engaged in studying phenomena related to magnetism, symmetry in physics and piezoelectricity. He had made such a strong impression on Marie that she was possessed by a yearning to return to France. In the autumn of 1894 she went back to Paris and, through the good offices of Lippmann, acquired funding to study the magnetic properties of various types of steel. It was precisely as a result of this research project that she began to frequent more assiduously the physicist who had touched her heart. This was the man who was to give her the surname by which she became famous all over the world: Pierre Curie. On 26 July 1895 Pierre and Marie were married in a civil ceremony in the town hall of Sceaux, where the Curie family lived. Marie's father Władysław, despite his advanced age, had made the long and arduous journey to be there at her side. The honeymoon was a cycling trip around the coasts of Brittany with an excursion southwards through the mountains of Auvergne, and the newlyweds set off on the new bicycles that were their wedding presents. By then the velocipede of the early nineteenth century, transformed into a bicycle in France in 1870, had reached a level of technological innovation that made it a fascinating and extremely popular means of transport. It featured two wheels of the same size, a chain drive and multiple-ratchet gears and the pneumatic tyres introduced by Dunlop with the wheel gliding on cushions of compressed air. The bicycle was an invention that characterised the entire twentieth century, right through to our own times. It led the English writer H. G. Wells to write: "Every time I see an adult on a bicycle, I no longer despair for the future of the human race." For women this invention was also an incredible driver for emancipation. In a piece written in 1897 the French journalist Georges Montorgueil stated:

> It is the bicycle which will lead to the emancipation of women. The leveling and egalitarian bicycle has created a third sex. This is not a man, this passerby in blousy knickers, calf exposed, torso set free and crowned with a boater. Is it a woman? The vigorous step, the lively walk, hands in the pockets, moving about at will and without a companion, settling in on café terraces, legs crossed, speech bold: this is a *bicycliste*.[3]

Also in 1895, on 28 December at the Grand Café on the Boulevard des Capucines, the Lumière brothers, who had patented the *cinematograph* two years earlier, organised the very first public film screening for which admission was charged. The motion pictures had an immediate and striking influence on popular culture.

The first eight years of the Curies' marriage coincided with extraordinary developments in chemistry and atomic physics. At the end of this same year of 1895, for instance, Wil-

[3] S. Quinn, *Marie Curie. A life*, Cambridge, MA 1995, pp. 126-127.

helm Roentgen discovered X-rays. Two years later J. J. Thomson discovered the electron, and some years after that Rutherford confirmed Goldstein's intuition regarding the existence of protons. Finally, in 1901 Max Planck published the quantum theory which was to earn him the Nobel Prize in Physics in 1918. In these years Marie and Pierre Curie were working intensely on several discoveries by Henri Becquerel. Let's take a closer look at what they were doing. As we said, 1895 was the year of the X-rays. On 22 December Roentgen photographed his wife's hand using these mysterious rays, intuiting one of the most revolutionary applications of the atom to human health. Furthermore, this brilliant scientific researcher also discerned in these rays two other exciting potential applications: he made an X-ray of the barrel of his gun and discovered an imperfection; then, from a photograph of the closed wooden box containing the small metal weights of his precision scales, he was able to distinctly discern the different shapes of these standard measures. The door had been opened towards industrial quality control of metal artefacts using X-rays and the way paved for what were to become known as metal detectors. It is almost hard to believe that, a few years later when X-rays had become so popular that even the press was full of them, an interviewer asked Roentgen what his thoughts had been at the time of his discovery and surprisingly he replied: "I didn't think anything at all at the time, I just went on investigating."

On 20 January 1896 Henri Poincaré reported on these new, unknown rays to the Académie des Sciences, also correlating them to phosphorescence. The phenomenon of phosphorescence had created a great stir in 1891 as a result of the work of the scientist Alexandre Edmond Becquerel, who had also invented a phosphoroscope. The phosphorescence we are talking about here had nothing at all to do with these new X-rays. In fact the phenomenon was described as the capacity of certain substances to continue to emit light even in the dark for a fairly long time if they have previously undergone a period of radiation. It appeared that during the illumination certain substances succeeded in storing enough energy for it to be subsequently emitted in the form of phosphorescence. This is the principle used in some of our modern clocks, for example, with hands covered in phosphorescent substances which are ‘charged’ during the day and at night re-emit this stored energy in the form of a faint green glow which allows us to see what time it is even in the dark. Present in the room where Poincaré was illustrating these most recent results of the chemical and physical sciences was Henri Becquerel, son of the inventor of the phosphoroscope. When he heard about his father’s research being associated with these wonderful X-rays, partly out of family pride and partly out of curiosity, he decided to take the experiments a step further. Using some uranium salts that had been prepared by his father about fifteen years earlier he set out to determine whether there really was a relation between these unknown new rays of Roentgen’s and the so-called uranium rays that gave rise to phosphorescence. He took the potassium uranium sulphate and prepared an apparatus consisting of light-sensitive paper sealed in an envelope covered with black cardboard (what is known in jargon as a photographic plate and works in a way similar to what we see on a modern bone X-ray). He placed a cross made of copper on top of the black cardboard and above that another dark sheet of the same size as the photographic paper completely covered with the powdered uranium salts. He wanted to expose the powder-covered surface to the sunlight for a few days and then put the whole apparatus back in the dark for a while and then finally print the negative to discover two things. Firstly, to see whether the rays had left an impression on the photographic plate, and secondly, whether they also behaved like X-rays which are absorbed by metals, hence also finding the image of the copper cross impressed on the plate.

The Greek philosopher Democritus, who predicted atomic science over two thousand years earlier, is – according to Dante – "he who ascribes the world to chance"[4] and in our story too chance plays a far from secondary role. Indeed, as chance would have it, February 1896 was a very rainy month in Paris and Becquerel was unable to expose his device to the

[4] Dante Alighieri, *Inferno*, IV, v. 136.

sunlight and had to postpone the experiment. What happened after this is related by William Crookes, an English scientist who was a guest in Becquerel's laboratory at the time.

> The sun persistently kept behind clouds for several days, and, tired of waiting (or with the unconscious prevision of genius), Becquerel developed the plate. To his astonishment, instead of a blank, as expected, the plate had darkened as strongly as if the uranium had been previously exposed to sunlight, the image of the copper cross shining out white against the black background.[5]

The emission of these rays was connected solely with the uranium and not with a prior exposure to sunlight. Clearly therefore this was something quite different from phosphorescence. Becquerel decided to stop there; he did not wish to proceed further along a path which was proving to deviate considerably from his father's discoveries.

In 1898 all the scientists were enthralled and almost obsessed by these blessed X-rays; hardly

[5] S. Quinn, *Marie Curie*, p. 142.

anyone believed that uranium rays could hold unbelievable surprises in store in terms of the structure of matter. The Curies, almost as if they were driven by an innate nonconformism in the choice of their research projects, decided to follow the path of the uranium rays. Nevertheless, there is no doubt that this decision was also significantly influenced by the great Irish scientist William Thomson, better known as Lord Kelvin, who was seventy-three at the time. In 1897 he published a series of articles dealing with the electrification of the air by uranium and its compounds, demonstrating that, in this regard, uranium rays behave exactly like X-rays. At the end of 1897, after J.J. Thomson had already discovered the electron, the Curies took up their studies exactly where Kelvin had left off, namely: aiming to quantify the electrical current generated in the air when it is traversed by uranic rays. The prime objective, therefore, was no longer the quality of the rays, but rather the quantity associated with them, that is, their energetic charge. The Curies' goal was hence to measure exactly how much electrical current is created in the air when rays are generated from uranium salts without any prior radiation.

Pierre and Marie had to come to terms with "the natural malevolence of inanimate things," and the approach was always the same: they had to make accurate measurements, "a job for an accountant, a wonk, an insect". And then they were obliged to brood, which is "unchristian, painful, boring and generally not worth it."[6] And then again they had "tried all the variations, went over all the things already done examined the causes and effects of each and every one." But in the end, in the face of enormous difficulties, unlike Primo Levi's Boero it never occurred to Pierre and Marie "to change careers", instead they decided to "make a picklock [to] force the doors"[7] of one of the innumerable secrets of the structure of matter. On 10 February 1898, after having analysed thirteen elements, the diary records two depressing comments: "no rays", "nothing clear". Marie realises that, rather than analysing simple elements, it would perhaps be more

[6] P. Levi, *Ottima è l'acqua*, in Id., *Vizio di forma*, Torino 1990, pp. 353–354.
[7] P. Levi, *Il sistema periodico*, Torino 1975, p. 23.

rewarding to examine the less pure, more 'dirty' compounds, since the rays could be concealed in some mysterious meander of humbler, more corrupt matter. On 17 February she carried out electrometric analysis on the air in the proximity of a black, pitchy material mined in the Joachimsthal region of the German-Czech border. This was where the German chemist Klaproth had discovered uranium in the year of the French revolution in the form of pitchblende, which was important at the time only as the raw material yielding the uranium-based pigments widely used in ceramic glazes. The electric current produced proved to be considerably greater than that of pure uranium or uranium salts. Marie was incredulous, and the next day she repeated the tests, with the same results. Greatly excited, she then immediately analysed another mineral of a very complex composition, it too therefore 'dirty'. This was aeschynite, which contains compounds of thorium – another element that had been discovered relatively recently, in 1828, by the Swiss chemist Berzelius. The analyses showed that pitchblende had a greater electrifying charge than aeschynite, while both produced more current than compounds of pure uranium. But that's not all: aeschynite doesn't contain any uranium, which means that Becquerel's rays can no longer be called uranic, but are perhaps a more general property of matter.

Marie's diaries record the details of the most minuscule measurements, all made using the formidable instruments constructed by that amazing experimental physicist who was her beloved husband Pierre. Finally, on 12 April, these absolutely revolutionary results were expounded at the Académie des Sciences in a paper entitled "Concerning the Rays Emitted by compounds of Uranium and Thorium". The report was read by Marie's teacher and mentor, Gabriel Lippmann, since because neither Marie nor Pierre were members of the Academy they were not permitted the honour of presenting their own research. Marie wrote in the paper that the facts discovered lead one "to think that these minerals contain an element much more active than uranium".[8] Marie's inner conviction

[8] S. Quinn, *Marie Curie*, p. 147.

opened up horizons that had been unthinkable up to then: namely, that the activity which she had measured – the electrification of the air – corresponds to an atomic, elementary property. The minds of the scientists began to be prey to the curiosity of discovering more about this possible new entry to Mendeleev's Periodic Table. Several years later Marie wrote, "I had a passionate desire to verify this hypothesis as rapidly as possible",[9] namely, the existence of a new chemical element. Marie began to work frenetically on chemical laboratory experiments, often using the courtyard of the École de Physique et Chimie Industrielles in place of a modern suction hood. Pierre was constantly at her side: they distilled, precipitated, crystallised and re-crystallised. Starting from dozens of kilos of 'dirty' minerals and coming up at the end with just a few milligrams of precious, mysterious substances. On 25 June Marie obtained a substance that was 150 times more active than uranium. She treated it with

[9] *Ibidem*, p. 150.

ammonia in aqueous media and discovered a solid precipitate 300 times more active than uranium; Pierre managed to isolate a substance 330 times more active than uranium. All the compounds identified that were more active than uranium can be divided into two groups: one that has properties very similar to bismuth and its compounds, and the other with characteristics that recall those of barium. They concentrated on the first group. On the eve of the French national holiday in memory of the storming of the Bastille, Pierre wrote in his notes that the isolated substance might truly be related to a new element positioned next to bismuth on the Periodic Table. On 18 July Becquerel, who was a member of the Académie des Sciences, for the same reasons as before read the *Compte Rendu* by Marie and Pierre entitled: "Concerning a New Radio-Active Substance Contained in Pitchblende". This was the first appearance of the adjective "radioactive" which was to bring such fame to the Curies. They confirmed that everything pointed in the direction of the existence of a new chemical element, but that so far they had not succeeded in separating it from bismuth: in any case, it proved to be 400 times more active than uranium. If we can succeed in isolating it, wrote Pierre, the name has already been chosen: it will be called polonium in honour of my wife's homeland and the symbol will be Po, since P on its own is already in use for the element phosphorus. In that same July Marie won the Gegner Prize, which she was to be awarded twice again in the future, amounting to a sum of 3,800 francs. This was a total break with tradition, since no woman had ever come close to achieving this honour. Despite this, however, the manner in which the news was communicated to her was singular to say the least: the scientists Henri Becquerel and Marcelin Berthelot wrote an official letter addressed to Pierre alone, which read as follows: "We should like to offer you our sincerest congratulations and would ask you to be so kind as to pay your wife our most respectful compliments."

In addition to her laboratory diaries, Marie filled the pages of small household ledgers with details of day-to-day expenses. She also kept track of the height and weight and the progress in walking and talking made by little Irène, born on 12 September 1897. Sometimes these domestic notebooks also contain information about the research activity, illustrating the extent to which this permeated Marie's entire everyday life. On 15 October we read: "expenses for a piece of cloth for Pierre's shirts", and immediately below "expenses for a large consignment of pitchblende."

By the end of November, Marie and Pierre had managed to isolate a substance 900 times more active than uranium, with properties very similar to the compounds of barium. On 20 December we read for the first time in Marie's notes that, in view of its extraordinary and terrible action, this latter element can actually be considered the emblem of radioactivity and ought therefore to be called radium. On the Feast of Saint Stephen 1898, the umpteenth *Compte Rendu* by Marie and Pierre was read: "Concerning a New Highly Radio-Active Substance contained in Pitchblende". And then, when the adventure of the scientist couple appeared to have reached its apex, an event took place that appears curious but, as we shall see, is fully in character for the two people involved. Marie and Pierre suddenly decided that their research should go separate ways, both linked to radioactivity but fundamentally very different. Pierre would concentrate on radioactivity as a general phenomenon of matter to be interpreted theoretically, whereas Marie was obsessed by the desire to isolate radium. For the first time Marie decided to devote herself primarily to chemistry, and Pierre primarily to physics. Many years later their daughter Irène confessed: "Pierre Curie was attracted above all by the fascinating problems posed by the mysterious rays emitted by these new materials. Marie Curie had the stubborn desire to see salts of pure radium, to measure radium's atomic weight."[10]

The most important opportunity for Marie and Pierre to wrap up the results of their studies was offered by the International Physics Congress convened in Paris for the Exposition Universelle of 1900 celebrating art and technology. The Eiffel Tower had already been looming over the Champ de Mars for ten years: comprising 18,000 pieces of wrought iron and

[10] *Ibidem*, p. 154.

two and a half million rivets, it stands 324 metres high and weighs around 10,000 tons; it was built in less than two years with only one death among the workmen. The Exposition Universelle of 1900 brought 50 million visitors to Paris. The real star of this particular World's Fair was the 'magic fluid' – electricity – which was changing the world. The American essayist Henry Adams confessed to having spent hours and hours "over the great dynamos watching them run noiselessly and smoothly as planets".[11] Amazing machines, spawned by human ingenuity and creativity, the modern erupting at the dawn of the twentieth century: the telephone, plumbing systems in homes, electric light, trams, the cinematograph, the bicycle, the car, lifts, underground railways. But also Impressionism in art – no longer mocked – the Symbolist poetry of Mallarmé and Verlaine recited at Montmartre, Debussy's *Prélude à l'après-midi d'un faune*. And elsewhere 1900 was the year of Puccini's *Tosca*, the year when

[11] *Ibidem*, p. 158.

the anarchist Gaetano Bresci assassinated the King of Italy, Umberto I of Savoy, of Mahler's *Fourth Symphony* and Thomas Mann's *Buddenbrooks*. Not to overlook the fact that Freud's psychoanalysis had just seen the light and an English archaeologist called Arthur Evans began the excavations in Crete that led him to discover the ruins of the ancient palace of Knossos. The Curies expounded their research at the Physics Congress of 1900 before an audience of scientists that included Kelvin, Lorentz, Van't Hoff, Arrhenius and many others. They closed their address with a question that paved the way to the chemistry and physics of the first forty years of the twentieth century:

> What is the source of energy coming from the Becquerel rays? Does it come from within the radioactive bodies, or from outside them?[12]

By studying this enigma, man was to arrive at an inconceivable understanding of the forces enclosed in the nucleus of an atom: knowledge

[12] *Ibidem*, p. 159.

of these enormous forces was to change the world we live in for ever.

Two years after the Congress, in July 1902, Marie announced that she had isolated a decigram of radium: "It had taken me almost four years," she later declared, "to produce the kind of evidence which chemical science demands, that radium is truly a new element." The article also announced that the atomic weight was 225 and concluded that "according to its atomic weight, it [radium] should be placed in the Mendeleev [periodic] table after barium in the column of alkaline earth metals."[13] Although the official announcement was made in an article published in the month of July, in a letter from her father Władysław dated 8 May 1902 we learn that Marie's discovery was already known to him: "and now you are in possession of salts of pure radium! If you consider the amount of work that has been spent to obtain it, it is certainly the most costly of chemical

[13] *Ibidem*, p. 172.

elements! What a pity it is that this work has only theoretical interest, as it seems."[14]

Six days later Władysław died at the age of seventy. As a result he was unable to rejoice when, in June 1903, Marie defended her doctoral thesis in physics for which she was awarded a *très honourable* mention. In 1902 a significant consensus had already begun to emerge apropos the nomination of the Curies for the Nobel Prize in Physics for the discovery of radioactivity; but perhaps the discovery was still too recent. There was in fact an equally important effect that had been discovered in 1896 which steered the Committee towards two other nominations. This was the Zeeman effect, for which the 1902 Nobel Prize in Physics was awarded to two Dutch physicists, Lorentz and Zeeman. However, by the following year the time was certainly ripe, despite which a dramatic turn of events took place: four members of the Académie des Sciences, including Marie's teacher and mentor

[14] *Ibidem*, p. 182.

Gabriel Lippmann, nominated Pierre Curie and Henri Becquerel, effectively eliminating Marie's contribution. The exclusion was deliberate and intentional, considering the fact that Lippmann himself had presented the first article about the discovery of radioactivity, signed by Marie alone, at the Académie des Sciences. He had also been a member of the scientific board examining her doctoral thesis and knew the whole story of the pitchblende. The concluding phrase of the letter of nomination reads: "it appears impossible for us to separate the names of the two physicists, and therefore we do not hesitate to propose to you that the Nobel Prize be shared between Mr. Becquerel and Mr. Curie."[15]

The signatories were fully aware that the two inseparable physicists – in both work and life – were not Mr Becquerel and Mr Curie, but the Curies, husband and wife. Then, however, came another ironic twist of fate: after the chemist Arrhenius, the most influential

[15] *Ibidem*, p. 188.

member of the Swedish Academy of Science was the mathematician Mittag-Leffler. Despite being a traditionalist, a dyed-in-the-wool monarchist and conservative, he also had what was considered at the time a certain extravagance of tastes which included being an advocate of women scientists. He was therefore indignant at Marie being ignored, and immediately wrote to Pierre advising of the fact that he had been nominated accompanied only by Becquerel. On 6 August Pierre replied, saying: "If it is true that one is seriously thinking about me [for the prize], I very much wish to be considered together with Madame Curie with respect to our research on radioactive bodies."[16] Mittag--Leffler set to work with alacrity and great diplomacy: he reinstated the 1902 nomination of Marie for the Nobel, which had been presented by a foreign Academician – the pathologist Charles Bouchard – establishing that the nominations made by foreigners could be permanent. It was thus that Marie Curie

[16] *Ibidem*, p. 189.

became the first woman to receive this most elevated recognition, and was to remain so up to her death. One year after her death another woman was awarded the Nobel, this time in Chemistry, being the second and, as we shall see, perpetuating the Curie epic.

The Curies did not go to Stockholm for the ceremony: Marie was not well; she had lost a baby in the fifth month of pregnancy and had fallen into a depression. Pierre sacrificed going to Stockholm to remain at her side: only Henri Becquerel was present. Notoriety and fame had no effect on the ethical imperatives of the Curies and they deliberately did not register the international patent for the isolation of radium. They wanted to leave it free so that the scientific community could carry out research in the field without impediments, thus fostering progress in this scientific field and the possible benefits for humanity. In 1933, speaking of this decision which seemed scandalous to some people, Marie clarified: "Humanity, surely, needs practical men. But it also needs dreamers, for whom the unselfish following of a purpose is so imperative that it becomes impossible for them to devote an important part of their attention to their material interest."[17]

Another great Polish scientist, Albert Sabin, pursued the same path in the 1960s for the anti-polio vaccine. He decided not to patent it, thus permitting very low costs and earning not a penny from it. He justified this stance by saying that he did not wish to patent the vaccine because it was his present to all the children in the world. A statement that seems almost naive in a world by then irremediably infected by the disease of capitalist profit at all costs.

For Marie, the years that followed the award of the Nobel Prize in Physics were full of hard trials but before that came a happy event: the birth of her second daughter Ève Dénise on 6 December 1904. Despite her role as mother of a family, Marie continued to work assiduously in the research laboratory and won a place on the faculty of the female teacher training school in Sèvres, which had been teaching science to girls since 1881. She was also concerned about

[17] B. Goldsmith, *Obsessive Genius*, pp. 198-199.

her husband's health: the effect of the radiation was beginning to undermine Pierre's physique and he became increasingly weaker. But his health did not have time to deteriorate further: on 19 April 1906, at the intersection between the Pont Neuf, the quais and rue Dauphine, Pierre was run over by a wagon carrying a load of about six tons which killed him on the spot. The Dean of the Faculty of Science at the Sorbonne, Paul Appell, went with Jean Perrin to Boulevard Kellerman bearing the tragic news. The door was opened by Grandpa and baby Ève. Seeing the grief-stricken expressions of Jean and Paul, Doctor Eugène Curie didn't let them utter a word: "My son is dead. What was he dreaming of this time?"[18] While the physical force of a wagon was crushing that small head, so packed with creativity and intelligence, other physical forces from the depths of the Earth's crust were shaking the city of San Francisco in one of the most devastating earthquakes in history.

[18] S. Quinn, *Marie Curie*, p. 230.

Less than a month after Pierre's death, Marie was appointed as successor to his chair at the Sorbonne, once again as the first women in history to hold such a post. On 5 November 1906 she began her first lesson with these words: "When one considers the progress in physics in the last decade one is surprised by the changes it has produced in our ideas about electricity and about matter."[19] And so, no tearful tribute to the memory of her husband, no pompous references to the historic importance of being the first woman to hold a Chair at the Sorbonne. But in her own diary the next day she confessed, addressing herself to Pierre: "What grief and what despair! You would have been happy to see me as a professor at the Sorbonne, but to do it in your place, my Pierre, could one dream of a thing more cruel. And how I suffered with it, and how depressed I am."[20] The years that preceded the second Nobel – the prize in Chemistry, awarded in 1911– were marked by grief and despair. Despite this, Marie continued

[19] *Ibidem*, p. 244.

[20] B. Goldsmith, *Obsessive Genius*, p. 144.

her research in radioactivity and published the first *Traité de radioactivité*. In this, incidentally, it is interesting to note the correction made in pencil ("M" in the place of "P") amending the normal manner adopted in France for a married lady, that is, to refer to her as Madame followed by the initial her husband's name rather than her own. We do not know who made this correction or when, but it is another sign of the sort of deification to which Marie was subject, attempting to make her into an icon of female emancipation. It was in this same period that Marie put herself forward as a candidate for the vacant seat of a physicist in the Académie des Sciences and was sensationally turned down on the strength of a single vote, an event greeted in the right-wing press with headlines such as "The Dreyfus Defeat" and references to the "Jewish-Huguenot faction". After this came the years of her liaison with the physicist Paul Langevin – married with three children – which caused great scandal and again unleashed the reactionary and hidebound right wing in an unprecedented xenophobic and defamatory campaign. After adultery proceedings were brought by Langevin's wife, Marie was urged by Arrhenius not to attend or collect the Nobel until the *affaire Langevin* had been settled in the courts. Regardless of this and despite health problems, Marie was determined to receive the Prize personally from King Gustav on 10 December 1911, and set off accompanied by her sister Bronia and her fourteen-year-old daughter Irène in a gesture of defiance towards the conformism and hypocrisy of a certain 'establishment'. The harsh trials she had gone through over recent years had made Marie more feisty and obstinate, and she forcefully underscored her role in the discovery of radium – the reason for the second Nobel Prize – and the search for radioactive phenomena. In her lecture to the Swedish Academy she stated: "The history of the discovery and isolation of this substance [radium] furnished proof of the hypothesis made by me, according to which *radioactivity is an atomic property of matter and can provide a method for finding new elements*."[21] The possessive adjective "my" and the pronouns "I",

[21] S. Quinn, *Marie Curie*, pp. 329-330.

"my" and "mine" are used extensively throughout this lecture. This woman was energetically claiming the right to intellectual acceptance and recognition.

The twentieth century was opening with signs of what were perhaps the most revolutionary changes in the history of human civilisation. The years that followed showed that the turbulent movements emerging on the global scene were to bring scientific and technological progress, certainly, but also planetary dramas on a vast scale. The toll of the First World War was over sixteen million dead between soldiers and civilians, while the Spanish influenza pandemic took over 50 million victims. But these were also the years in which social classes hitherto excluded from everything began to claim rights and citizenship. The principles of progress, equality and emancipation, the trade union movements, the ideas of socialism and communism and the October Revolution began to radically alter the social dynamics of many countries. Even during the First World War Marie found a way to place her skills at the service of her adopted country. With the help of her daughter Irène, she succeeded in organising a military radiology service to help wounded soldiers both at the front and in peripheral centres. Over a million X-ray procedures were carried out all over Europe during the Great War.

The end of the War also coincided with the reacquisition of national sovereignty by the Polish people after 123 years. The resurrection of her homeland, which Marie greeted with joy in a letter to her brother Józef, was sadly to be the prelude to even more devastating disasters for this beleaguered country. The 1920s witnessed the spreading fame of Marie Curie throughout the world, the American consecration of 1922 and the continuation of research into the structure of matter, for which every three years the famous Solvay Conferences are held in Brussels, begun in 1911 by the Belgian industrialist and philanthropist Ernest Solvay. The group photo of one of these Conferences is an object of reverence for the students and teachers who frequent this educational complex: a brief glance that calls to memory hours and hours of academic toil pursuing the arduous paths mapped out by Schrödinger and Heisenberg, Pauli and Brillouin, Dirac and de

Broglie, Born and Bohr, Compton and Langevin, Lorentz and Einstein and – naturally – Marie herself, the only one without initials before her name but with the title 'Madame' instead. Even more moving is the short film documenting the Solvay Conference of 1927: the figures that every day populate the concepts and the blackboards of these lecture halls are brought to life through the marvellous art of the Lumière brothers. [The short film is accompanied by a soundtrack consisting of the third movement *Adagio molto e cantabile* of Symphony no. 9 in D minor, Op. 125 by Ludwig van Beethoven (Bonn, 1770-Vienna, 1827)]. In October 1933 Marie took part in the Solvay Conference for the last time, and was accompanied by her daughter Irène and her son-in-law Frédéric Joliot, both scientists. They presented some sensational research, hypothesising that the proton is not an elementary particle but is made up of ulterior, sub-nuclear particles. Marie was by this time tortured by numerous ailments, almost entirely attributable to the massive doses of radiation accumulated during the years spent at the Radium Institute. Less than a year after this Congress, at dawn on 4

July 1934, Marie died of an "aplastic pernicious anaemia of rapid, feverish development." As her daughter Ève poignantly recalls:

> Marie Curie, who had always worn black in life, was laid to rest all in white, her white hair laying bare the immense forehead, the face at peace. Her rough hands, calloused, hardened, deeply burned by radium, had lost their familiar, nervous movement. They were stretched out on the sheet, stiff and fearfully motionless – those hands which had worked so much.[22]

The image of formidable intellectual toil succinctly condensed into the hands which had worked so much. It is a perfect symbol of what is, for the experimental scientist, the indissoluble link between intellect, reason and practical-manual work. The funeral was simple and private and Marie was laid to rest beside Pierre in the cemetery of Sceaux; her brother Józef and her sister Bronia had both come from Warsaw bringing with them, each unbeknownst to the other, the tribute that their

[22] *Ibidem*, p. 432.

sister would have appreciated most: brother and sister sprinkled over the coffin a handful of Polish soil.

Marie had lived for almost seven decades in a period of European history as culturally fertile as it was dramatic and harrowing. The matter which Faraday had left still mysteriously enigmatic was now understood at inconceivable levels. Electrons, protons, neutrons, X-rays, quantum theory, relativity, quantum mechanics, Raman effect, wave-particle dualism, by now part of the history of science, were about to open up a new chapter of subatomic physics that would generate unbelievable progress, as well, alas, as Hiroshima and Nagasaki. As mentioned at the beginning, Marie was born along with Wagner's *Ring* tetralogy and Verdi's *Don Carlo* and now the melodrama is a story without a future, if not in the relistening. Twelve-note composition and serial music had already grown with Schönberg and Berg, not to mention Stravinsky who in 1913 had scandalised the Parisians with *Le sacre du printemps*. We started with the *bande à Manet* and over the years a whole array of artistic movements had exploded: Expressionism, Futurism, Cubism, Dadaism and the Fauves. In 1935 Le Corbusier published the *Ville Radieuse*, a book on the problems connected with city planning. As mentioned, Pirandello was born in the same year as Marie and now, in the year of her death was awarded the Nobel Prize for Literature, after those awarded in the interim to Giosuè Carducci and Grazia Deledda, as well as Thomas Mann and Rudyard Kipling. But, unfortunately, 1934 was also the year after Hitler came to power and the twelfth year of the Fascist era: the world was dramatically hurtling towards another terrible and agonising maelstrom.

And so, the story of Marie ends here, but not that of her legend, nor that connected with her genes and her relationship with the Kingdom of Sweden. Perhaps it was another sign of destiny, but the Nobel Prize in Physics was not awarded in the year that Marie died and in the autumn days of 1934 when the Nobel Committee was maturing this very important decision, in a modest laboratory in the centre of Rome an Italian physicist interpreted with ingenious intuition the slowing down of neutrons by paraffin and laid the foundations of a new era in energy; four years later he was awarded the Nobel. As you will have realised, I am talking about Enrico Fermi. Slightly over a year after Marie's death another woman, the second in history, was admitted to the Olympus of world science, and it was again a Curie. It was Marie's daughter Irène who received, from the same king who had crowned her mother in 1911, the Nobel Prize in Chemistry together with her husband Frédéric Joliot. 32 years later this other Curie couple bowed before the King of Sweden, they too triumphant adventurers in the mysteries of the subatomic world, and at the same time sacrificial victims. In the space of two years, between 1955 and 1958, they were taken from their children Pierre and Hélène, scientists in their turn and living witnesses of this extraordinary dynasty. And even that's not the end of the story. In 1965, thirty years after Marie's death, the son of Gustav V of Sweden awarded the Nobel Peace Prize to Unicef, the United Nations International Children's Emergency Fund, which was accepted by Mr Labouisse in his capacity as Director. The Director was accompanied by his wife, who appeared to be exceedingly moved by the occasion, almost as if the ceremony had a significance for her that no-one else could feel. Then suddenly something in the elegant carriage of the lady appeared to jog the memory of the very air within the hall: the nucleotide pairs of thousands of genes well-known in that place once more revived a never-ending legend. For the fourth time a Curie woman in this hallowed spot: Ève Dénise, the younger daughter of Marie and Pierre, arm-in-arm with Mr Labouisse. She was the daughter assigned by destiny to have the honour and the duty of keeping the memory of her mother alive for over a century: she died in New York at nearly 103 years of age.

It was also she who was present, along with Marie's grandchildren and their families, at the solemn ceremony when the ashes of her parents were transferred from the cemetery of Sceaux to the Panthéon in the presence of the highest authorities and the Presidents of France and Poland, François Mitterand and Lech Wałęsa. I should like to salute this extraordinary woman, for whom we have just celebrated in 2011 the award of the highest scientific honour conferred upon her – the Nobel Prize in Chemistry – by inviting you to read several passages from the speech made by the President of the French

Republic during this ceremony on 20 April 1995. His words are particularly significant and rich in reflections that are still relevant today. I also feel it is fitting to accompany this reading with the notes of another great Pole, who also died in France about twenty years before Marie was born, who was laid to rest in the beautiful cemetery of Père Lachaise framed by flowers in the red and white colours of his homeland which are perennially renewed by generations of faithful admirers. [The reading of the passages from the speech of President Mitterand is accompanied by the notes of the second movement *Romanze. Larghetto* of the Concerto for piano and orchestra no. 1 in E minor by Frédéric Chopin (Żelazowa Wola, 1810-Paris, 1849)].

> Today's ceremony is of particular significance since it marks the entry into the Pantheon of the first woman in our history honoured for her own accomplishments. Just a short walk from here, in this street that bears the name of her and her husband, stand the two pavilions of the Radium Institute, in the very place where Marie's destiny unfolded. In the small garden between the two she planted a rose bush which continues to blossom. Just a little

further on, in Rue Vaquelin, was the modest shed where radium was isolated. The distance between these two sites and the Panthéon is very small, but what an incredible journey had to be made, a path strewn with harsh trials, but again – how great the glory! We should never be able to understand the strength of will of a whole lifetime, so many obstacles overcome, without reflecting on her native land, lacerated by centuries of oppression and subservience to foreign powers, but at the same time with the strength of a thousand-year tradition of unbreakable resistance. From her childhood, Maria Skłodowska resisted: against the humiliations of Tsarist power, against the limitations of woman's condition, against all the dogmas which attempted to restrict her. She wanted to control her own life and to pursue her own destiny, and she possessed all the qualities necessary to do so. She was, naturally, sustained by ambition, but more than anything by the love of science which she discovered at an early age and which never ceased to nourish her before it finally killed her. She and her beloved Pierre were kindred spirits in so many ways: they had the same philosophy of science, a shared anxiety about social injustice, the same literary tastes, especially for the novels of Émile Zola, Pierre's first gift to Marie, the same lack of interest in material things and passion for freedom. Both always refused to profit financially from their research by taking out patents. And then her courage, her generosity and her spirit of solidarity, so quietly displayed during the First World War in her participation in the struggle of her adoptive homeland. In the military health service Marie organised the equipment of around twenty vans as mobile radiology installations, as well as over 200 permanent stations in the battle zones. Her daughter Irène was at her side: alas, during these months of total dedication to love of their fellow men, both were exposed to huge doses of radiation, the terrible effects of which would later bring their lives to an end. Today, we still admire the shared virtues of these two people, who were separated too soon: their ardour and their enthusiasm, their obstinate self-sacrifice, their rigour and moderation in all things, their taste for contemplation and the strength of solitude. And there was one trait they shared more than any other: disinterestedness, which was in their eyes the bedrock of all scientific ethics. But in Marie there was also something else: the exemplary struggle of a woman who decided to assert her abilities in a society where intellectual endeavour and public responsibility were all too often restricted to men. What, then, is the beauty and nobility of science? The endless desire to push back the frontiers of knowledge, to hunt out the secrets of matter and of life without preconceptions about the eventual consequences. This boundless faith is, like hope, made up partly of desire and partly of dream. Without it there can be no progress for the spirit. The battle of science is a battle of reason against the forces of obscurantism; it is the struggle of freedom of the mind against the slavery of ignorance. Greater freedom means the alleviation of suffering. Freedom must be increased to reduce the material and spiritual dependency that obstructs man's capacity to choose his own destiny.

All this can be condensed in the words of Maria Skłodowska herself:

> I am among those who think that science has great beauty. Neither do I believe that the spirit of adventure runs any risk of disappearing in our world. If I see anything vital around me, it is precisely that spirit of adventure, which seems indestructible.[23]

[23] B. Goldsmith, *Obsessive Genius*, p. 233.

Just as the wonderful and heartrending strains of the Polish composer have just died out today in this hall, so the echo of the words of President Mitterand resounded then beneath the dome of the French temple which had taken in the ashes of that tiny woman and scientist and Polish patriot Maria Salomea Skłodowska. And the motto written large beneath the pediment of the great mausoleum "Aux grands hommes, la patrie reconnaissante" (*To great men from their grateful homeland*) appeared at that moment, as it still does today, to flicker with the faintest smile of benevolent irony.