VALUE-ORIENTED EDUCATION SERIES

MARIE SKLODOWSKA CURIE

GENERAL EDITOR
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Marie Sklodowska Curie

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This monograph is part of a series on Value-oriented Education centered on three values: *Illumination, Heroism and Harmony*. The research, preparation and publication of the monographs that form part of this series are the result of the work and cooperation of several research teams of the Sri Aurobindo International Institute of Educational Research (SAIIER) at Auroville.

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Illumination, Heroism and Harmony

Marie Sklodowska Curie

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Preface

The task of preparing teaching-learning material for value-oriented education is enormous.

There is, first, the idea that value-oriented education should be exploratory rather than prescriptive, and that the teaching-learning material should provide to the learners a growing experience of exploration.

Secondly, it is rightly contended that the proper inspiration to turn to value-orientation is provided by biographies, autobiographical accounts, personal anecdotes, epistles, short poems, stories of humour, stories of human interest, brief passages filled with pregnant meanings, reflective short essays written in well-chiselled language, plays, powerful accounts of historical events, statements of personal experiences of values in actual situations of life, and similar other statements of scientific, philosophical, artistic and literary expression.

Thirdly, we may take into account the contemporary fact that the entire world is moving rapidly towards the synthesis of the East and the West, and in that context, it seems obvious that our teaching-learning material should foster the gradual familiarisation of students with global themes of universal significance as also those that underline the importance of diversity in unity. This implies that the material should bring the students nearer to their cultural heritage, but also to the highest that is available

in the cultural experiences of the world at large.

Fourthly, an attempt should be made to select from Indian and world history such examples that could illustrate the theme of the upward progress of humankind. The selected research material could be multi-sided, and it should be presented in such a way that teachers can make use of it in the manner and in the context that they need in specific situations that might obtain or that can be created in respect of the students.

The research team at the Sri Aurobindo International Institute of Educational Research (SAIIER) has attempted the creation of the relevant teaching-learning material, and they have decided to present the same in the form of monographs. The total number of these monographs will be around eighty to eighty-five.

It appears that there are three major powers that uplift life to higher and higher normative levels, and the value of these powers, if well illustrated, could be effectively conveyed to the learners for their upliftment. These powers are those of illumination, heroism and harmony.

It may be useful to explore the meanings of these terms – illumination, heroism and harmony – since the aim of these monographs is to provide material for a study of what is sought to be conveyed through these three terms. We offer here exploratory statements in regard to these three terms.

Illumination is that ignition of inner light in which meaning and value of substance and life-movement are seized, understood, comprehended, held, and possessed, stimulating and inspiring guided action and application and creativity culminating in joy, delight, even ecstasy. The width, depth and height of the light and vision determine the degrees of illumination, and when they reach the splendour and glory of synthesis and harmony, illumination ripens into wisdom. Wisdom, too, has varying degrees that can uncover powers of knowledge and action, which reveal unsuspected secrets and unimagined skills of art and craft of creativity and effectiveness.

Heroism is, essentially, inspired force and self-giving and sacrifice in the operations of will that is applied to the quest, reali-

sation and triumph of meaning and value against the resistance of limitations and obstacles by means of courage, battle and adventure. There are degrees and heights of heroism determined by the intensity, persistence and vastness of sacrifice. Heroism attains the highest states of greatness and refinement when it is guided by the highest wisdom and inspired by the sense of service to the ends of justice and harmony, as well as when tasks are executed with consummate skill.

Harmony is a progressive state and action of synthesis and equilibrium generated by the creative force of joy and beauty and delight that combines and unites knowledge and peace and stability with will and action and growth and development. Without harmony, there is no perfection, even though there could be maximisation of one or more elements of our nature. When illumination and heroism join and engender relations of mutuality and unity, each is perfected by the other and creativity is endless.

This monograph is devoted to Marie Sklodowska Curie whose destiny was closely connected to the immense progress in scientific research made at the beginning of the 20th century.

Marie Curie, famous for her scientific genius, was a woman of action and courage as well as a researcher engaged in the application of her discoveries. Like all pioneers, she is known for her audacity and incredible determination. Her discovery of radioactivity was at the origin of a new science and in turn led to other revolutionary discoveries. Radioactivity was born of a spark of genius and Marie Curie's unshakable faith in science.

Marie was not alone in this adventure: we cannot dissociate Pierre and Marie Curie. They were dedicated to scientific research as a high ideal for which they were prepared to give themselves entirely. Neither was interested in fame or material profit. Their common dream was science without borders at the service of humanity. .

After the death of Pierre, Marie continued this mission alone. In spite of the danger from the possible misuse of the discoveries of modern physics, she kept her faith intact. She never doubted

that science would be useful for the good of humanity and she proved this with her commitment. In this way she was a being of harmony, constantly working for scientific progress.

"I am among those who think that science has a great beauty. (...) Neither do I believe that the spirit of adventure runs any risk of disappearing from our world," she stated near the end of her life in 1933.

Indeed, Marie Curie can be seen as a discoverer and therefore an illuminator. She is also an example of a heroic adventurer, since she pursued her mission, despite all difficulties and calamities. As a servant of humanity, she was also a harmoniser and a benevolent soldier in the march of human progress.

"The Unknown is not Unknowable; it need not remain the unknown for us, unless we choose ignorance or persist in our first limitations. For all things that are not unknowable, all things in the universe, there correspond in that universe faculties which can take cognisance of them, and in man, the microcosm, these faculties are always existent and at a certain stage capable of development."

"...fundamentally, all possible knowledge is knowledge within the power of humanity."

— Sri Aurobindo, *The Life Divine*

Introduction

There are some lives more than others that are marked by destiny and whose extraordinary path is the stuff of which legends are made. Marie Curie, known as one of the greatest scientific geniuses of the century, was also a woman who knew, when needed, how to actively engage herself in the service of science. She entirely devoted herself to scientific research, having made this choice very early in her life and no obstacle could ever divert her from her mission.

Yet the obstacles were numerous: Marie was poor, she was born in an occupied country, Poland, under the yoke of Russia, and she was a woman in a world in which studies were reserved for men. Later, grief, solitude and illness did not succeed to discourage her. She gave herself with ardour to the ideal of science dedicated to progress and it is thus that after having isolated radium, she would develop applications for this discovery, especially in the therapeutic domain.

Marie had several dreams and she fought for them: there was her patriotic dream of national liberation, because her country was oppressed by Russia and Marie dreamt of a free Poland. In Warsaw she became very quickly aware of the danger it represented to express herself in her mother tongue and to be an intellectual. There was her humanitarian dream, to relieve human

suffering, to educate people: she realized this and gave the world the means to treat serious illnesses. She who so much loved to learn dedicated part of her life to transmitting knowledge: already in adolescence, wishing for social justice she devoted herself to the education of children with inadequate means. And finally there was her greatest dream, her scientific dream: even as a young girl she had been fascinated by her father's physics apparatus. She was ready to sacrifice this dream to help her family but destiny intervened. Entering a laboratory of physics and chemistry for the first time, she met the force of her vocation. The call of science was so strong! It was an inner call that Marie could not resist: she had to study, study everything that science had discovered. So she decided to leave her family and her country.

In Paris, where she studied at the Faculty of Sciences at the Sorbonne, the most prestigious university of the time, Marie was a woman, in a century in which universities were essentially open to men. For Marie, it was also the struggle of a woman who stood out in a society that reserved for men certain domains of knowledge and responsibility that lead to teaching and research.

Sometimes she paid dearly as she broke the taboos of that settled society and in spite of the prejudice and scepticism of her colleagues she was at the forefront. When Marie launched into research, she fought her greatest battle. She had the intuition that the astonishing radiation emitted by uranium, the origin of which no one knew, was due to the existence of a new element. Her hypothesis was daring, but Marie did not hesitate. With perseverance and a self-confidence out of the ordinary, she went looking for this substance, in the heart of a ton of raw material. The element hitherto unknown was Radium. With her husband the physicist Pierre Curie, she succeeded in isolating Radium in conditions of exceptional difficulty. Pierre and Marie knew nothing of the dangers of the radiation of this radioactive material which they exposed themselves to daily.

A spark of genius, years of crushing work, Pierre and Marie gave birth to a new science: radioactivity, following it through its first steps.

When her companion died an accidental death, Marie was devastated but did not abandon the work. To accomplish the mission that she had been given, she went to the limits of her strength. Marie, a force in action, from the deadly battlefields of World War I, where she took her place at the front as the director of the new mobile radiological service which she created, to her almost permanent struggle against fatigue and pain due to exposure to radiation that ruined her health before killing her.

Before her death in 1934, she had created an Institute of Radium in both Paris and Warsaw, trained numerous scientists to succeed her and left as a testament to future generations of researchers, what only she could have written: a monumental work about radioactivity.

Even more extraordinarily, Marie, two time winner of the Nobel Prize, passed the torch to her daughter Irene Joliot-Curie, who carried out research with her husband Frederic Joliot. For their discoveries in artificial radioactivity, they received the Nobel Prize in Chemistry in 1935: five Nobel Prizes in the same family, a unique occurrence.

Marie Curie lives in our memory as an exceptional person: one who was fired up by the ideals of justice, peace and social progress. She had the genius of discovery, the intuition that science could open the doors of a new world. Among scientists and geniuses, Marie Curie remains a legendary figure, a unique example of grandeur of soul and simplicity of heart.

To illustrate this monograph we have drawn from the biography written by Eve Curie in 1938, four years after Marie's death. Eve, the youngest daughter of Pierre and Marie Curie, lived in New York where she died at the age of 103 on 26 October 2007.

In the introduction to her book, Madame Curie, *Eve Curie wrote: "It would have been a crime to add the slightest ornament to this story, so like a myth. I have not related a single anecdote of which I am not sure. I have not deformed a single essential phrase or so much as invented the colour of a dress. The facts are as stated; the quoted words were actually pronounced."*

The rigour of Eve Curie is a tribute to the scientific spirit that her parents cherished; it is for this reason that we have chosen this source from among numerous other biographies available. As additional material, extracts have been taken from "Autobiographical Notes" written by Marie Curie in 1923.

Marie Curie at work in her laboratory, 1911

Marie Sklodowska Curie

The life of Marie Curie contains prodigies in such number that one would like to tell her story like a legend.

— Eve Curie

Polish childhood and adolescence

Marya Sklodowska was born on 7th November 1867 in Warsaw. She was the youngest in a family of five children, composed of four girls: Sophie or Zosia (1862), Bronislava or Bronya (1865), Helena or Hela (1866), Marya (1867), and one boy, Joseph, Josio (1863). Little Marya, the favorite child, had many pet names, such as Manya, Manusia, Anupecio, as was often the case in Poland where affectionate names and diminutives are much used. Marya was a very lively child who loved to learn: at the age of four she could read, but her parents were prudent pedagogues and dreaded the precocity of their little girl. They wanted Marya to play the games of her age. When she asked, "May I read?" her mother often replied: "Manusia, I wish you would go into the

garden instead!"

> [...]A very special timidity reddened Manya's cheeks when she broached the subject of reading: the year before, in the country, Bronya, finding it extremely boring to have to learn the whole alphabet by herself, had taken it into her head to make her sister an experiment in education to 'play teacher' to her. For several weeks the little girls had amused themselves by arranging, in what was often enough an arbitrary order, their letters cut out of cardboard. Then, one morning, while Bronya was faltering out a very simple reading lesson to her parents, Manya grew impatient, took the opened book from her hands, and read aloud the opening sentence on the page. At first, flattered by the silence that surrounded her, she continued this fascinating game; but suddenly panic seized her. One look at the stupefied faces of Mr. and Mrs. Sklodowski, another of Bronya's sulky stare, a few unintelligible stammers, an irrepressible sob, and instead of the infant prodigy there was only a baby of four, crying in a doleful voice through her tears:
> "Beg pardon! Pardon! I didn't do it on purpose. It's not my fault, it's not Bronya's fault! It is only because it was so easy!"

Wladyslaw Sklodowski, Marya's father, was a mathematics and physics teacher in a lycée in Warsaw. He would be Marya's first teacher of physics and chemistry. His wife Bronislava was the directress of one of the best private schools for girls in Warsaw. Having received an excellent education, she was also a musician who played the piano and loved to sing. She had to stop working at the school to take care of their five children. The Sklodowski's were not wealthy but the atmosphere in the family home was peaceful and joyous.

However, outside their home, the same harmony did not prevail! At the time of Marya's birth, Poland was like 'a prisoner in

chains', and had not been an independent country for most of that century. Warsaw was in the part of Poland controlled by the Czar. Polish patriots were determined to regain control of their nation. The Sklodowski's were part of the intelligentsia who had for objectives, first, national liberation, and second the education of the people.

[...] Its heroes [Poland's] were no longer those warriors armed with scythes, those who charged the Cossacks and died saying 'what happiness to die for my country!' The new heroes were the intellectuals, the artists, priests, schoolteachers – those upon whom the mind of the new generation depended. Their courage consisted in forcing themselves to be hypocrites, and in supporting any humiliation rather than lose the places in which the Tsar still tolerated them and from which they could secretly influence Polish youth, guide their compatriots.

[...] It was a cruel fate, in the year 1872, to be a Pole, a "Russian subject", and to belong to that vibrant "intelligentsia" whose nerves were so near the surface; among them revolt was ever brooding, and they suffered more painfully than any other class in society from the servitude imposed upon them.

Exactly a century before, greedy sovereigns, the powerful neighbors of a greatly weakened state, had decided Poland's ruin. Three successive partitions had dismembered it into fragments which became officially German, Russian and Austrian. On several occasions the Poles rose against their oppressors: They succeeded only in strengthening the bounds that held them prisoners. After the failure of the heroic revolution of 1831 the tsar Nicholas dictated severe measures of reprisal in Russian Poland. The patriots were imprisoned and deported in a body; their property was confiscated...

In this context, from childhood, Marya learned to fight. All the same, some burdens are very heavy for a little girl; at school for example, the teacher chose her to undergo the interrogation of the inspector who had the task to monitor whether the young students were learning Russian and czarist history, and certainly, that no courses were being taught in Polish! She felt humiliated and intensely disliked these moments when she was obliged to hide the truth, but as always throughout her life, Marya put on a brave face.

[...] On the threshold, laced into his fine uniform – yellow pantaloons and a blue tunic with shiny buttons – appeared M. Honberg, inspector of private boarding schools in the city of Warsaw. [...] M. Honberg, accepting the chair offered by Mlle Tupalska, seated himself heavily.

"Please call one of these young people."

In the third row Marya Sklodovska instinctively turned her frightened little face toward the window. A prayer rose in her: "Please god, make it someone else...Not me...Not me!"

But she knew very well that the choice would fall upon her. She knew that she was almost always chosen for the government inspector's questioning, since she was the most knowledgeable and since she spoke Russian perfectly.

At the sound of her name she straightened up. She felt very warm. No, she felt cold. A dreadful shame seized her by the throat.

"Your prayer", snapped M. Honberg, whose attitude showed his indifference and boredom.

Manya recited 'Our Father' correctly, in a voice without color or expression. One of the subtlest humiliations the Tsar had discovered was to make the Polish children say their Catholic prayers every day in Russian. Thus, while pretending to respect their faith, he was able to profane what they reverenced.

Manya's parents watched over the education of each of their children. But brutally, in 1876, at the age of nine, Manya was thrust from the protected world of childhood: her older sister Zosia caught typhoid fever and died; two years later, it was her mother's turn, exhausted after five years of struggle against tuberculosis. At the end of the 19th century, no one knew either the cause or the cure of this illness and rare was the family that escaped from its curse.

In this educated and united family in which Manya grew up, the ties strengthened even more after the disappearance of Zosia and Madame Sklodowska. Affection and solidarity continued to unite these beings throughout their lives.

Marya completed her secondary studies in 1883; she was first in her class and received a gold medal; it was the third gold medal for the Sklodowski family.

Marya then took a year off; she stayed either with her parents or with friends, discovering her country. When she returned to Warsaw, she spent a year giving private lessons to help cover the expenses of her family.

[...] She was healthy, honest, sensitive and gay. She had a loving heart. She was, as her teachers say 'remarkably gifted'; she was a brilliant student. But on the whole no startling characteristics distinguished her from the children who grew up with her: nothing had yet indicated her genius.

[...] It might be supposed that Manya was at this time a young lady without a dowry, active and sensible, whose only interest was in building up her list of pupils. This supposition would be untrue. She had bravely accepted the toilsome life of private lessons, by necessity; but she had another life, passionate and secret. Like every Pole of her place and time, she was exalted by dreams.

There was one dream common to all the youth: the dream

of nationhood. In their projects for the future, the desire to serve Poland took precedence over personal ambition, marriage and love.

[...] The philosophical doctrines of the period gave this national progressionism a special direction. For some years past the positivism of Comte and Spencer had instigated new ways of thinking in Europe. At the same time, the work of Pasteur, Darwin and Claude Bernard had endowed the exact science with immense prestige. At Warsaw as elsewhere, even more than elsewhere, intellectual fashion grew away from the romantic spirit; it disdained the world of art and sensibility for a while; and the young people, inclined by their age to downright judgments, suddenly placed chemistry and biology above literature and deserted the writer's cult for that of the scientist.
In free countries this current of ideas was allowed to develop publicly; but such was not the case in Poland, when every manifestation of independence of mind was regarded with suspicion. The new theories made their way and spread by underground routes.

[...] Manya allied herself with some ardent positivists. [...] At first timid and untrusting, before long Manya was conquered by her friends' bold ideas.

Like her classmates, Marya hoped to obtain an advanced degree even though women were not welcome at the University of Warsaw. Marya and Bronya joined other friends attending lessons in anatomy, natural history and sociology at the 'Floating University'. This illegal night school got its name from the fact that its classes met in changing locations, the better to evade the watchful eyes of the czarist authorities. Its students' lofty goal went beyond mere self-improvement. They hoped their grassroots educational movement would raise the likelihood of eventual Polish liberation.

The aim of the Floating University was not only to continue the education of young people just out of secondary school: in their turn the students were to become educators.

> [...] How is one to imagine the fervor of this girl of seventeen? Her childhood had been passed before mysterious divinities: the physics apparatus in her father's study; even before the science had been made 'fashionable' M. Sklodovski had transmitted his passionate curiosity to her. But that world was not enough for impetuous Manya; she plunged eagerly into other sections of the world's knowledge; she grasped at Auguste Comte and social evolution, she dreamed no longer of mathematics and chemistry alone, but wished to reform the established order and enlighten the masses of the people.

Forty years later, Maria would remember those days in her Autobiographical Notes.

> Other means of instruction came to me through my being one of an enthusiastic group of young men and women of Warsaw, who united in a common desire to study, and whose activities were at the same time social and patriotic. It was one of those groups of Polish youths who believed that the hope of their country lay in a great effort to develop the intellectual and moral strength of the nation, and that such an effort would lead to a better national situation. The nearest purpose was to work at one's own instruction and to provide means of instruction for workmen and peasants. In accordance with this program we agreed among ourselves to give evening courses, each one teaching what he knew best. There is no need to say that this was a secret organization, which made everything extremely difficult. There were in our group very devoted young people who, as I still believe today, could do truly useful work.
> I have a lively memory of that sympathetic atmosphere of

social and intellectual comradeship. Truly the means of action were poor and the results obtained could not be very considerable and yet I persist in believing that the ideas that then guided us are the only ones which can lead to true social progress. We cannot hope to build a better world without improving the individual. Towards this end, each of us must work toward his own highest improvement accepting at the same time his share of responsibility in the general life of humanity, our particular duty being to help those to whom we feel we can be most useful.

This make-shift education could not compare with the curriculum at any of the major European universities that admitted women. Although Maria understood this fact, at the Floating University she did get a taste of progressive thought and an introduction to new developments in sciences.

But what was happening for Bronya? Marya knew that the secret wish of her sister was to study medicine in Paris. Unfortunately, the savings that Bronya counted and recounted at the kitchen table were not enough to help her to realize her dream. But Marya found a way! Bronya would leave first and she proposed to work to help her. When Bronya had completed her studies Marya in turn would join her in Paris and live with her.

A governess in the countryside

This is how Bronya left for Paris and Marya became a governess in a home in Warsaw. She first found a position in the city that allowed her to remain near her father. But life was too expensive; Marya could not save enough money. She decided on exile to the countryside where she would be better paid and less tempted by expenses: she found a position as a governess, a hundred kilometers from Warsaw. Marya stayed for three years in a bourgeois family that owned a small estate and a sugar factory where she was well received and well treated. Yet this life and work seemed

a little too conventional, too far from her ideals of justice and social progress; Marya as always had her progressive ideas, she needed to dedicate herself to more audacious projects to serve these ideals. She dreamed of 'educating the people'. So she decided to start a clandestine course for the children of Polish peasants that were illiterate. She wanted to 'awaken these young brains to the beauty of the national language and history'. Marya knew that if she were denounced, she risked deportation to Siberia. Nevertheless she threw herself into the adventure, with the agreement of her patrons with whom she succeeded to share her enthusiasm. Marya's room became a classroom!

[...] The dauntless girl went up to her room and waited until a noise of boots on the stairs, mingling with the shuffle of bare feet, announced the arrival of her disciples. She had borrowed a pine table and some chairs so that they could practice their writing comfortably. She had taken enough from her savings to buy them some copybooks and the pen which the numbed little fingers managed with such difficulty. When seven or eight young peasants were installed in the big room with chalked walls, Manya and Bronka Z. were barely able to maintain order and rescue the unhappy pupils who, sniffling and snorting with anguish, could not spell a difficult word.

[...] In most of their bright eyes appeared a naive and violent desire to accomplish some day, those fabulous acts: reading and writing.

At night when the children had left, Marya worked further to enrich her own knowledge.

[...] It was indeed an all-powerful instinct that made her sit

every night at her desk, reading volumes of sociology and physics borrowed from the factory library, or perfecting her knowledge of mathematics by correspondence with her father.

Marya was a school teacher for six long years. It was in the course of her last year in Warsaw that she had the occasion to work for the first time in her life in a physics and chemistry laboratory. This first contact with the atmosphere of a science laboratory was a revelation; Marya had finally found her vocation! Her destiny began to unfold!

[...] Her vocation, for so long uncertain, had flashed into life. She was summoned to obey a secret order. She was suddenly in a hurry, whipped onward. When she took the test tubes of the Museum of Industry and Agriculture into her fine, clever hands, Manya returned, as if by magic, to the absorbing memory of her childhood, to her father's physics apparatus, motionless in its glass case, with which, in the old days, she had always wanted to play. She had taken up the thread of her life again.

Finally, in 1891, she called Bronya for help; she wanted to go to Paris. She wrote to her sister:

"You can put me up anywhere; I shall not bother you; I promise that I shall not be a bore or create disorder. I implore you to answer me but very frankly."

Bronya was married and had completed her studies, she could accommodate her younger sister. She replied to Marya that she could come as soon as possible.

Marya prepared for her departure: Paris was waiting, she was 24 years old.

She said good-bye to her father on the platform of the railway station. Promising to return quickly to live with him again, she

boarded the train, almost ashamed of her good fortune.

> [...] In the night pierced with whistles and the clank of old iron the fourth-class carriage was passing across Germany. Crouched down on her folding chair, her legs muffled up, her luggage, which she carefully counted from time to time, piled close around her, Manya tasted her divine joy. She mused upon the past, upon this magic departure for which she had waited so long. She tried to imagine the future. In her humility she thought that she would soon be back again in her native town, that she would find a snug little place as teacher there...
> She was far, very far, from thinking that when she entered this train she had at last chosen between obscurity and a blazing light, between the pettiness of equal days and an immense life.

The train brought her finally towards her dream and her destiny. Let us ponder one moment upon this enigma: at the age of 17 Marya knew four languages perfectly, in addition to her mother tongue: Russian, French, German, English ('English a little less well' she said). Her intellectual faculties were exceptional, her thirst to learn, to understand, and her endurance seemed to be without limit. Yet this remarkable girl had been placed as a governess for six long years! How is it that no one remarked on her highly distinctive capacities? Why had her vocation not been found out? How did her genius go unnoticed?

Eve Curie expresses the question and its reply in this way:

> [...] Strange paradox: the high quality of Manya's youthful companions and their lively intelligence may be taken as explaining the secret of a haunting enigma. How was it that nobody discovered the extraordinary vocation, the genius, of this young girl? Why had she not been sent to study in Paris, instead of being allowed to seek employment as a governess?

Living among exceptional beings, with three young people who carried off diplomas and medals, who were brilliant, ambitious and ardent for work like herself, the future Marie Curie did not seem remarkable. In an intellectually narrow circle, surprising gifts are soon shown; they provoke astonishment and comment; but here, under the same roof, Josef, Bronya, Hela and Manya were all growing up, rivaling one another in aptitude and knowledge. Thus it came about that nobody, neither the old nor the young, recognized in one of these children the signs of a great mind; nobody was touched by its first radiations. There was no suspicion that Manya might be of a different essence from her brother and sisters, and she had no idea of it herself.

Paris at last!

You cannot hope to build a better world without improving the individuals. To that end, each of us must work for our own improvement and, at the same time, share a general responsibility for all humanity, our particularity being to aid those to whom we think we can be most useful.

— Marie Curie

After two days of traveling, Marya met Bronya and Casimir who had come to meet her at the platform of the railway station. Once settled, Marya enrolled at the Faculty of Sciences and every morning traversed Paris in a horse drawn double-decker bus to reach the university. For Marya, France was a country of liberty. "The familiar grip of servitude" had gone at last! We well understand Marya's almost euphoric happiness.

Then Manya, Marya became Marie. Marie, at last a student at the Faculty of Sciences of the Sorbonne, the most famous of

universities. Life with Bronya and her husband Casimir, a young doctor, was agreeable and fraternal. Bronya and Casimir often received Polish friends and Casimir very much liked to have discussions with his young sister-in-law.

But Marie, well surrounded with affection, had a need for quiet and contemplation, and more, she lost time in traveling which cost her dearly. After a few months, she moved to a small rented room in the Latin Quarter, a district around the Sorbonne University where many students lived.

Marie's life as a student was austere and solitary. She allowed no distractions and made no superfluous expenditures. If she had only the strict minimum, it was not only because she was poor, but also because she wanted to live so. It was not a life without joy, on the contrary. Because Marie wanted to learn everything about the secrets of science, she studied with passion and fervor, with joy in her heart in spite of the cold, the poverty and the privations; she was convinced that only the acquisition of knowledge could relieve the suffering and foster the progress of humanity. She therefore gave herself entirely to her studies and did not give way to weakness.

She showed the same qualities all her life: she was tenacious, persevering; once the goal to reach was identified she never abandoned it and never left a work unfinished. It was a beautiful life that strove for the realization of an ideal of progress. She moved forward with great strides. No task was too difficult, she excelled in all fields. She wrote,

> My brother-in-law, recalling later these years of work under the conditions I have just described, jokingly referred to them as "the heroic period of my sister-in-law's life." For myself, I shall always consider one of the best memories of my life that period of solitary years exclusively devoted to the studies, finally within my reach, for which I had waited so long.

Remembering those difficult days, Marie always dedicated

part of her time to teaching. Years later at the Radium Institute there were numerous scientists, often young Poles, to whom she gave her support.

[...] Work!...Work! Plunged altogether into study, intoxicated by her progress, Marie felt herself equal to learning everything mankind had ever discovered. She attended courses in mathematics, physics and chemistry. Manual technique and the minute precision of scientific experiment became familiar to her, little by little; soon she was to have the joy of being charged by Professor Lippmann with researches of no great importance, which nevertheless permitted her to show her deftness and the originality of her mind. In the physics laboratory of the Sorbonne, a high and wide room queerly ornamented by two little staircases which led to an interior gallery, Marie Sklodowska timidly tried her strength.

She had a passionate love for that atmosphere of attention and silence, the "climate" of the laboratory, which she was to prefer to any other up to her last day. She was on her feet, always on her feet, in front of an oak table supporting precision instruments, or else in front of the chemical hood where some material in fusion bubbled away, worried at by the fierce blowpipe. She was hardly to be distinguished, in her big smock and wrinkled linen from the thoughtful young men who bent beside her over the other blowpipes and other instruments. Like them, she respected the concentration of the place. She made no noise, she pronounced no useless word.

[...] Re-reading a little poem of my mother's, written in Polish, on this time of her life, and remembering the accounts of it that she sometimes gave me, with many a smile and humorous remark, looking at the only portrait of herself which she dearly cherished: the small photograph of a student girl with daring eyes and determine chin, I have

felt that she never ceased to prefer these hard, fervent days to all others.

Ah! How harshly the youth of the student passes,
While all around her, with passion ever fresh,
Other youths search eagerly for easy pleasures!
And yet in solitude
She lives, obscure and blessed,
For in her cell she finds the ardor
That makes her heart immense.

But the blessed time is effaced.
She must leave the land of Science
To go out and struggle for her bread
On the grey roads of life.
Often and often then, her weary spirit
Returns beneath the roofs
To the corner ever dear to her heart
Where silent labor dwelled
And where a world of memory has rested.

She wrote to her brother Josef:

"It seems that life is not easy for any of us. But what of that? We must have perseverance and above all confidence in ourselves. We must believe that we are gifted for something, and that this thing, at whatever cost, must be attained. Perhaps everything will turn out very well, at the moment when we least expect it..."

She was proud of her poverty; proud of living alone and independent in a foreign city. Working in the evening beneath the lamp in her poor room she felt that her destiny, still insignificant, mysteriously related itself to the high existences she most admired, and that she became the humble unknown companion of those great scientists of the past,

who were, like her, shut into their ill-lighted cells, like her detached from their time, and, like her, spurred their minds to pass beyond the summed acquired knowledge.
[...] Yes, these four heroic years were, not the happiest of Marie Curie's life, but the most perfect in her eyes, the nearest to those summits, of the human mission towards which her gaze had been trained.
An immense enthusiasm gave this girl of twenty-six the power to ignore the trials and privations she endured; to magnify her sordid existence into magic.

At the Faculty of Sciences at the Sorbonne there were very few young women on the benches of the amphitheatre when, in 1893, Marie received first place as Master of Physics. This first place allowed her to obtain a scholarship to prepare for a second degree in mathematics, which she received taking second place in 1894. Later, Marie reimbursed the grant that she had been awarded to the Secretary of the Alexandrowich Foundation, who was stunned by this unprecedented initiative. Marie wished that the funds that helped her would serve another poor young student.

For the work that was assigned to her at the research laboratory of Professor Lippmann, she needed to meet someone with knowledge of magnetism. This is how, one evening in the spring of 1894, she was introduced to a young physicist, already known in France and abroad for his work: Pierre Curie.

"She met a man whose genius was akin to her"

[...] Pierre Curie was born in Paris, in Rue Cuvier, on May 15, 1859. He was the second son of a physician, Dr Eugène Curie, who was himself the son of a doctor. The family was of Alsatian origin, and Protestant. The Curies, once of the lower bourgeoisie, had through generations, become intellectuals and scientists. Pierre's father had to practice medicine to earn his living; but he was devoted to research.

He had been for some time a worker in the laboratory of the Museum of Natural History in Paris, and he was the author of works on tuberculosis infection.
His two sons, Jacques and Pierre, were drawn by science from their infancy. Pierre, with his independent and dreamy mind, was unable to adapt himself to systematic work and discipline. He had never been to school. Dr Curie, understanding that the boy was too original to be a brilliant pupil, had at first instructed him himself, and afterward had confided him to a remarkable teacher, Mr. Bazille. This liberal education had borne fruit: Pierre Curie was a bachelor of science at sixteen and had a Master's Degree in physics at eighteen. At nineteen he was appointed laboratory assistant to Professor Desaims in the Faculty of Science – a position he occupied for five years. He was engaged in research with his brother Jacques, who also had his degree and was a laboratory worker at the Sorbonne. The two young physicists soon announced the discovery of the important phenomenon of "piezoelectricity", and their experimental work led them to invent a new apparatus with many practical uses: piezoelectric quartz, which measures small quantities of electricity with precision.
In 1883 the two brothers separated with regret: Jacques was appointed professor at Montpellier, and Pierre became chief of laboratory at the School of Physics and Chemistry of the City of Paris. Even though he devoted much time to demonstrations for the pupils, he pursued his theoretical work on crystalline physics. This work led to the formulation of the principles of symmetry, which was to become one of the bases of modern science.

Marie wrote,

"It was in 1894 that I first met Pierre Curie. One of my compatriots, a professor at the University of Fribourg, having called upon me, invited me to his home, with a

young physicist of Paris, whom he knew and esteemed highly. Upon entering the room I perceived, standing framed by the French window opening on the balcony, a tall young man with auburn hair and large, limpid eyes. I noticed the grave and gentle expression of his face, as well as a certain abandon in his attitude, suggesting the dreamer absorbed in his reflections. He showed me a simple cordiality and seemed to me very sympathetic. After that first interview he expressed the desire to see me again and to continue our conversation of that evening on scientific and social subjects in which he and I were both interested, and on which we seemed to have similar opinions."

[...] Pierre and Marie immediately discovered an intellectual affinity, which was very soon transformed into deeper feeling.

On August 10th 1894 Pierre wrote to Marie,

"It would be a fine thing, just the same, in which I hardly believe, to pass our lives near each other, hypnotized by our dreams: your patriotic dream, our humanitarian dream, and our scientific dream.

Of all those dreams the last is, I believe, the only legitimate one. I mean by that that we are powerless to change the social order and, even if we were not, we should not know what to do; in taking action, no matter in what direction, we should never be sure

Bicycles as a wedding gift (1895)

of not doing more harm than good, by retarding some inevitable evolution. From the scientific point of view, on the contrary, we may hope to do something, the ground is solider here, and any discovery that we may make, however small, will remain acquired knowledge."

Pierre and Marie had much in common: concerns about social justice, the same reverential passion for science, a sense of material disinterestedness and freedom; they also shared a love of nature and the same tastes in literature. For each of them, a beautiful life meant a life of work devoted to science and to progress.

[...] In July 1895, they were married at the town hall at Sceaux, where Pierre's parents lived. They were given money as a wedding present which they used to buy a bicycle for each of them, and long, sometimes adventurous cycle rides came to become their way of relaxing. Their life was otherwise quietly monotonous, a life filled with work and study.
Persuaded by his father and by Marie, Pierre submitted his doctoral thesis in 1895. It concerned various types of magnetism that is now known as Curie's Law.

Marie received the authorization, exceptional at that time, to work in the laboratory with her husband. She was also preparing for the examination for a fellowship in Secondary Education in which she secured first place in 1896. Should we say: as usual?

It must not be forgotten that if women were rare on the benches of the university, young foreign women were even more so.

A master's degree in physics, a master's degree in mathematics, a fellowship in secondary education, and a study on the magnetic properties of steel, this is what had been achieved by this young woman, 29 years old, who had arrived in Paris five years earlier.

But Marie did not stop there and in 1897 she decided on what no other woman before her had dared: to become a Doctor of

Science. Marie had to decide on a subject for her thesis; it was a very important moment that would determine her future.

In the same year her first child, Irène, was born on 12th September.

The birth of a new science

In every particle, atom, molecule, cell of Matter
there lives hidden and works unknown
all the omniscience of the eternal and the omnipotence
of the infinite.

— Sri Aurobindo, *Essays Human and Divine*

[...] She had to choose a subject of research which would furnish fertile and original material.
At this critical moment Pierre's advice had an importance which cannot be neglected. With respect to her husband, the young woman regarded herself as an apprentice: he was an older physicist, much more experienced than she. He was even, to put it exactly, her chief, her "boss".

But without a doubt Marie's character, her intimate nature had a great part in this all-important choice. From childhood the Polish girl had carried the curiosity and daring of an explorer with her. This was the instinct that had driven her to leave Warsaw for Paris and the Sorbonne, and had made her prefer a solitary room in the Latin Quarter to the Dulskis' downy nest. In her walks in the woods she always chose the wild trail or the unfrequented road.
At this moment she was like a traveler musing on a long voyage. Bent over the globe and pointing out, in some far country, a strange name that excited his imagination, the

traveler suddenly decides to go there and nowhere else: so Marie, going through the reports of the latest experimental studies, was attracted by the publication of the French scientist Henri Becquerel of the preceding year. She and Pierre already knew this work; she read it over again and studied it with her usual care.

After Roentgen's discovery of X rays, Henri Poincaré conceived the idea of determining whether rays like the X ray were emitted by 'fluorescent' bodies under the action of light. Attracted by the same problem, Henri Becquerel examined the salts of a 'rare metal', uranium. Instead of finding the phenomenon he had expected, he observed another, altogether different and incomprehensible: he found that uranium salts spontaneously emitted, without exposure to light, some rays of unknown nature. A compound of uranium, placed on a photographic plate surrounded by black paper, made an impression on the plate through the paper. And like the X ray, these astonishing 'uranic' salts discharged an electroscope by rendering the surrounding air a conductor.

For the first time a physicist had observed the phenomenon to which Marie Curie was later to give the name of radioactivity. But the nature of the radiation and its origin remained an enigma...

Becquerel's discovery fascinated the Curies. They asked themselves whence came the energy, tiny, to be sure, which uranium compounds constantly disengaged in a form of radiation. And what was the nature of this radiation? Here was an engrossing subject of research, a doctor's thesis!

Marie then set to work, going step-by-step into the unknown; very quickly she had the intuition that something was taking place inside the atom and that radioactivity was an atomic phenomenon, a general property of matter. Her hypothesis was daring, she was curious and precise, fascinated by what she had found. The new radiation had to be analyzed with precision to identify

the cause that provoked it. For her research, Marie Curie had at her disposition the equipment designed by Pierre to measure very low quantities of electricity, this remarkable equipment would be used for more than fifty years. She made rapid progress.

In one year she observed the rays emitted by uranium and by thorium, separated the first radioactive element, polonium, in July 1898, followed in December by that of radium.

Pierre and Marie had the genius to retain the idea that the atoms of radioactive elements disintegrate spontaneously, what they would call "the cataclysm of atomic transformation."

The atom transforms itself! It was a revolution in regard to the conception of an immutable indivisible atom! This discovery shattered the scientific dogmas of the time and eminent professors must have quivered on the benches of the amphitheatre of the Academy of Sciences when Pierre and Marie Curie explained their hypothesis!

They had, indeed, to confront doubts and prejudices, to fight against the formation that 'it is not possible'. But nothing would stop Pierre and Marie. They united their efforts and after several years of arduous work they isolated radium. In a small test tube they then brandished the 'new element' — luminous, blue in color, and dangerously marvelous! It was a spark of Promethean fire that these two persistent scientists extracted from the residue of uranium, inert in appearance: a spark that would illumine scientific research for a century to come.

[...] These were unique moments in her unique life. The lay-man forms a theatrical and wholly false idea of the research worker and of his discoveries. 'The moment of the discovery' does not always exist: the scientist's work is too tenuous, too divided, for the certainty of success to crackle out suddenly in the midst of his laborious toil like a stroke of lighting, dazzling him by its fire. Marie standing in front of her apparatus, perhaps never experienced the sudden intoxication of triumph. This intoxication was spread over several days of decisive labor, made feverish by a mag-

Pierre and Marie Curie in their laboratory

nificent hope. But it must have been an exultant moment when, convinced by the rigorous reasoning of her brain that she was on the trail of new matter.

[...] It was barely four years earlier that Marie had written:
"Life is not easy for any of us. But what of that? We must

have perseverance and above all confidence in ourselves. We must believe that we are gifted for something, and that this thing, at whatever cost, must be attained."

That "something" was to throw science upon a path hitherto unsuspected.

[...]By the force of her intuition the physicist had shown to herself that the wonderful substance must exist. She decreed its existence. But its incognito still had to be broken. Now she would have to verify hypothesis by experiment, isolate the material and see it. She must be able to announce with certainty: "it is there."

[...]A man chosen at random from a crowd to read an account of the discovery of radium would not have doubted for one moment that radium existed: beings whose critical sense has not been sharpened and simultaneously deformed by specialized culture keep their imaginations fresh. They are ready to accept an unexpected fact, however extraordinary it may appear, and to wonder at it.

The physicist colleagues of the Curies received the news in slightly different fashion. The special properties of polonium and radium upset fundamental theories in which scientists had believed for centuries. How was one to explain the spontaneous radiation of the radioactive bodies? The discovery upset a world of acquired knowledge and contradicted the most firmly established ideas on the composition of matter. Thus the physicist kept on the reserve. He was violently interested in Pierre and Marie's work, he could perceive its infinite developments, but before being convinced he awaited the acquisition of decisive results.

The attitude of the chemist was even more downright. By definition, a chemist only believes in the existence of a new substance when he has seen the substance, touched it, weighed and examined it, confronted it with acids, bottled it, and when he has determined its 'atomic weight.'

Now, up to the present, nobody had 'seen' radium. Nobody knew the atomic weight of radium. And the chemists,

faithful to their principles, conclude: 'No atomic weight, no radium. Show us some radium and we will believe you.'
To show polonium and radium to the incredulous, to prove to the world the existence of their 'children' and to complete their own conviction, M. and Mme Curie were now to labor for four years.
[...]What does it matter to Science if her passionate servants are rich or poor, happy or unhappy, healthy or ill? She knows that they have been created to seek and to discover, and that they will seek and find until their strength dries up at its source. It is not in a scientist's power to struggle against her vocation: even on his days of disgust or rebellion his steps lead him inevitably back to his laboratory apparatus. One cannot, therefore, be surprised at the brilliance of the researches Pierre and Marie carried out successfully during these difficult years. Radioactivity grew and developed, exhausting little by little the pair of physicists who had given it life.

The birth of this new science, Marie described with simplicity in her Autobiographical Notes,

"It seemed to me that the first thing to do was to measure the phenomenon with precision. In this I decided to use that property of the rays which enabled them to discharge an electroscope. However, instead of the usual electroscope, I used a more perfect apparatus. One of the models of the apparatus used by me for these first measurements is now in the College of Physicians and Surgeons in Philadelphia. I was not long in obtaining interesting results. My determinations showed that the emission of the rays is an atomic property of the uranium, whatever the physical or chemical conditions of the salt were. Any substance containing uranium is much more active in emitting rays, as it contains more of this element.
I then thought to find out if there were other substances

possessing this remarkable property of uranium, and soon found that substances containing thorium behaved in a similar way, and that this behavior depended similarly on an atomic property of thorium. I was now about to undertake a detailed study of the uranium and thorium rays when I discovered a new interesting fact.

I had occasion to examine a certain number of minerals. A few of them showed activity; they were those containing either uranium or thorium. The activity of these minerals would have had nothing astonishing about it, if it had been in proportion to the quantities of uranium or thorium contained in them. But it was not so. Some of these minerals revealed an activity three or four times greater than that of uranium. I verified this surprising fact carefully, and could not doubt its truth. Speculating about the reason for this, there seemed to be but one explanation. There must be, I thought, some unknown substance, very active, in these minerals. My husband agreed with me and I urged that we search at once for this hypothetical substance, thinking that, with joined efforts, a result would be quickly obtained. Neither of us could foresee that in beginning this work we were to enter the path of a new science which we should follow for all our future.

Of course, I did not expect, even at the beginning, to find a new element in any large quantity, as the minerals had already been analyzed with some precision. At least, I thought there might be as much as one per cent of the unknown substance in the minerals. But the more we worked, the clearer we realized that the new radioactive element could exist only in quite minute proportion and that, in consequence, its activity must be very great. Would we have insisted, despite the scarcity of our means of research, if we had known the true proportion of what we were searching for, no one can tell; all that can be said now is that the constant progress of our work held us absorbed in a passionate research, while the difficulties were

ever increasing. As a matter of fact, it was only after several years of most arduous labor that we finally succeeded in completely separating the new substance, now known to everybody as radium.

Here is, briefly, the story of the search and discovery.

As we did not know, at the beginning, any of the chemical properties of the unknown substance, but only that it emits rays, it was by these rays that we had to search. We first undertook the analysis of pitchblende from St. Joachimsthal. Analyzing this ore by the usual chemical methods, we added an examination of its different parts for radioactivity, by the use of our delicate electrical apparatus. This was the foundation of a new method of chemical analysis which, following our work has been extended, with the result that a large number of radioactive elements have been discovered.

In a few weeks we could be convinced that our prevision had been right, for the activity was concentrating in a regular way. And, in a few months, we could separate from the pitchblende a substance accompanying the bismuth, much more active than uranium, and having well defined chemical properties. In July, 1898, we announced the existence of this new substance, to which I gave the name of polonium, in memory of my native country. While engaged in this work on polonium, we had also discovered that, accompanying the barium separated from the pitchblende, there was another new element. After several months more of close work we were able to separate this second new substance, which was afterwards shown to be much more important than polonium. In December, 1898, we could announce the discovery of this new and now famous element, to which we gave the name of radium.

However, the greatest part of the material work had yet to be done. We had, to be sure, discovered the existence of the remarkable new elements, but it was chiefly by their radiant properties that these new substances were distin-

guished from the bismuth and barium with which they were mixed in minute quantities. We had still to separate them as pure elements. On this work we now started.

We were very poorly equipped with facilities for this purpose. It was necessary to subject large quantities of ore to careful chemical treatment. We had no money, no suitable laboratory, and no personal help for our great and difficult undertaking. It was like creating something out of nothing, and if my earlier studying years had once been called by my brother-in-law the heroic period of my life, I can say without exaggeration that the period on which my husband and I now entered was truly the heroic one of our common life.

We knew by our experiments that in the treatment of pitchblende at the uranium plant of St. Joachimsthal, radium must have been left in the residues, and, with the permission of the Austrian government, which owned the plant, we succeeded in securing a certain quantity of these residues, then quite valueless, and used them for extraction of radium. How glad I was when the sacks arrived, with the brown dust mixed with pine needles, and when the activity proved even greater than that of the primitive ore! It was a stroke of luck that the residues had not been thrown far away or disposed of in some way, but left in a heap in the pine wood near the plant. Some time later, the Austrian government, on the proposition of the Academy of Science of Vienna, let us have several tons of similar residues at a low price. With this material was prepared all the radium I had in my laboratory up to the date when I received the precious gift from the American women.

The School of Physics could give us no suitable premises, but for lack of anything better, the Director permitted us to use an abandoned shed which had been in service as a dissecting room of the School of Medicine. Its glass roof did not afford complete shelter against rain; the heat was suffocating in summer, and the bitter cold of winter was

only a little lessened by the iron stove, except in its immediate vicinity. There was no question of obtaining the needed proper apparatus in common use by chemists. We simply had some old pine-wood tables with furnaces and gas burners. We had to use the adjoining yard for those of our chemical operations that involved producing irritating gases; even then the gas often filled our shed. With this equipment we entered on our exhausting work.

Yet it was in this miserable old shed that we passed the best and happiest years of our life, devoting our entire days to our work. Often I had to prepare our lunch in the shed, so as not to interrupt some particularly important operation. Sometimes I had to spend a whole day mixing a boiling mass with a heavy iron rod nearly as large as myself. I would be broken with fatigue at the day's end. Other days, on the contrary, the work would be a most minute and delicate fractional crystallization, in the effort to concentrate the radium. I was then annoyed by the floating dust of iron and coal from which I could not protect my precious products. But I shall never be able to express the joy of the untroubled quietness of this atmosphere of research and the excitement of actual progress with the confident hope of still better results. The feeling of discouragement that sometimes came after some unsuccessful toil did not last long and gave way to renewed activity. We had happy moments devoted to a quiet discussion of our work, walking around our shed.

One of our joys was to go into our workroom at night; we then perceived on all sides the feebly luminous silhouettes of the bottles or capsules containing our products. It was really a lovely sight and one always new to us. The glowing tubes looked like faint, fairy lights.

Thus the months passed, and our efforts, hardly interrupted by short vacations, brought forth more and more complete evidence. Our faith grew ever stronger, and our work being more and more known, we found means to get

new quantities of raw material and to carry on some of our crude processes in a factory, allowing me to give more time to the delicate finishing treatment.

At this stage I devoted myself especially to the purification of the radium, my husband being absorbed by the study of the physical properties of the rays emitted by the new substances. It was only after treating one ton of pitch-blende residues that I could get definite results. Indeed we know to-day that even in the best minerals there are not more than a few decigrammes of radium in a ton of raw material.

At last the time came when the isolated substances showed all the characters of a pure chemical body. This body, the radium, gives a characteristic spectrum, and I was able to determine for it an atomic weight much higher than that of the barium. This was achieved in 1902. I then possessed one decigram of very pure radium chloride. It had taken me almost four years to produce the kind of evidence which chemical science demands, that radium is truly a new element. One year would probably have been enough for the same purpose, if reasonable means had been at my disposal. The demonstration that cost so much effort was the basis of the new science of radioactivity."

Radium would become an extraordinary tool for the exploration of the structure of matter and radioactivity would open the way to the exploration of the atom and the nucleus of the atom. The transformation of the atomic nucleus would be applied in numerous disciplines. It would lead to the dawning of new scientific domains, to radiochemistry, to nuclear physics, to the dating of past events, to the study of cosmic rays and elementary particles. The work of Pierre and Marie Curie was also the base from which nuclear physics and molecular biology have developed.

Because of it, chemists have explored the intimate structure of matter, astrophysicists have explained the life and death of the stars and geophysicists have made progress in the study of terres-

trial dynamics through the observation of the release of heat due to radioactive disintegration. Doctors and biologists have used radioactive traces and found new treatments, in particular, for cancer.

Fame and glory

[...] the means that science has put at our disposal eliminate the peril of the subversion and destruction of an effete civilization by stronger primitive peoples, but it is the resurgence of the barbarian in ourselves, in civilized man, that is the peril, and this we see all around us. For that is bound to come if there is no high or strenuous mental and moral ideal controlling and uplifting the vital and physical man in us and no spiritual ideal liberating himself into his inner being.[1]

— Sri Aurobindo

[...] Radioactivity, born in France, rapidly conquered in foreign countries. From 1900 on, letters signed by the greatest names in science arrived in the Rue Lhomond.
[...] In 1903 two English scientists, Ramsay and Soddy, demonstrated that radium continually disengaged a small quantity of a gas, Helium. This was the first known example of a transformation of atoms. [...] Radio elements, even when they seemed to be unchangeable, were in a state of spontaneous evolution: the more rapid their rate of transformation, the more powerful their 'activity.'
"Here we have a veritable theory of the transmutation of simple bodies, but not as the alchemists understood it

1 *The Life Divine*, Chapter 28, *The Divine Life*, p. 1052, Sri Aurobindo Ashram Publication Trust, 1970.

(Pierre Curie was to write). Inorganic matter must have evolved, necessarily, through the ages, and followed immutable laws."

"We", "with joined effort" Marie wrote. For many years and under material conditions that have become legendary, Pierre and Marie associated their efforts. This collaboration of two scientists, two geniuses, is unique to that time. In their written report they used "we" or "one of us", and it would be impossible to distinguish the work of one from the other.

[...]We cannot and must not attempt to find out what should be credited to Marie and what to Pierre during these eight years it should be exactly what the husband and wife did not want. The personal genius of Pierre Curie is known to us by the original work he had accomplished before this collaboration. His wife's genius appears to us in the first intuition of discovery, the brilliant start and it was to reappear again, solitary, when Marie Curie, the widow unflinchingly carried the weight of a new science and consecrated it through research, step by step, to its harmonious expansion. We therefore have formal proof that in the fusion of their two efforts, in this superior alliance of man and woman, the exchange was equal.
Let this certainty suffice for our curiosity and admiration.

After the isolation of radium, Pierre and Marie would take a decision that would have important consequences on their lives as well as those of their family. This decision, taken together and without the least hesitation, perfectly illustrates the dedication of their lives to the ideals of scientific research. Any other decision, according to Marie, would have been contrary to the scientific spirit.

"Physicists always publish their researches completely. If our discovery has a commercial future that is an accident

by which we must not profit. And radium is going to be of use in treating diseases... It seems to me impossible to take advantage of that."

After Marie said this, Pierre gave the American engineers the information they requested.

"In agreement with me (*Marie Curie was to write twenty years later*) Pierre Curie decided to take no material profit from our discovery: in consequence we took out no patent and we have published the results of our research without reserves, as well as the processes of preparation of radium. Moreover, we gave interested persons all the information they requested. This was a great benefit to the radium industry, which was enabled to develop in full liberty, first in France and then abroad, furnishing to scientists and doctors the products they needed. As a matter of fact this industry is still using today, almost without modification, the processes which we pointed out.
The 'Buffalo Society of Natural Science' has offered me, as a souvenir, a publication on the development of the radium industry in the United States, accompanied by photographic reproductions of the letters in which Pierre Curie replied most fully to the questions asked by the American engineers (1902 and 1903)."

And later on she will make this statement:

"A large number of my friends affirm, not without valid reasons, that if Pierre Curie and I had guaranteed our rights, we would have acquired the financial means necessary to the creation of a satisfactory Radium Institute, without encountering the obstacles which were a handicap to both of us, and which are still a handicap for me. Nevertheless, I am still convinced that we were right.
Humanity certainly needs practical men, who get the most

out of their work, and without forgetting the general good, safeguard their own interests. But humanity also needs dreamers, for whom the disinterested development of an enterprise is so captivating that it becomes impossible for them to devote their care to their own material profit. Without the slightest doubt, these dreamers do not deserve wealth because they do not desire it. Even so, a well-organized society should assure to such workers the efficient means of accomplishing their task, in a life freed from material care and freely consecrated to research."

In 1903, Marie and Pierre were awarded half the Nobel Prize in Physics. The citation read: "in recognition of the extraordinary services they have rendered by their joint researches on the radiation phenomena discovered by Professor Henri Becquerel." Henri Becquerel was awarded the other half for his discovery of spontaneous radioactivity.

Pierre and Marie could not go to Sweden, their visit was put off until a later date.

On 6th December 1904 Marie gave birth to a second child, a little girl that she named Eve.

In 1905 Pierre and Marie finally went to Stockholm.

[...] On June 6, 1905, in the name of his wife and himself, Pierre Curie spoke on radium before the Academy of Science of Stockholm. He evoked the consequences of the discovery of radium. In physics it profoundly modified the fundamental principles of mechanics. In chemistry it stirred up bold hypotheses on the source of energy which supplied the radioactive phenomena. In geology, in meteorology, it was 'the key to phenomena which had never been explained before'. In biology, last of all, the action of radium on cancerous cells had proved efficacious.

"Radium had enriched Knowledge and served the Good. But could it also serve the Evil?

One may also imagine (*Pierre said in concluding*) that in criminal hands radium might become very dangerous and here we may ask ourselves if humanity has anything to gain by learning the secrets of nature, if it is ripe enough to profit by them, or if knowledge is not harmful. The example of Nobel's discoveries is characteristic: powerful explosives have permitted men to perform admirable work. They are also a terrible means of destruction in the hands of criminals who lead the peoples towards war.
I am among those who think, with Nobel, that humanity will obtain more good than evil from the new discoveries."

[...] Radioactivity, generation of heat, production of helium gas and emanation, spontaneous self-destruction, how far we have traveled from the old theories on inert matter, on the immovable atom! Not more than five years before, scientists had believed our universe to be composed of defined substances, elements fixed forever. Now it was seen that with every second of passing time radium particles were expelling atoms of helium gas from themselves and were hurling them forth with enormous force. The residue of this tiny, terrifying explosion, which Marie was to call 'the cataclysm of atomic transformation,' was a gaseous atom of emanation which was transformed in his turn. Thus the radio elements formed strange and cruel families in which each member was created by the spontaneous transformation of the mother substance: radium was a 'descendant' of uranium, polonium a descendant of radium. These bodies, created at every instant, destroyed themselves according to eternal law; each radio element lost half of its substance in a time which was always the same, which was to be called its 'period'. To diminish itself by one half, uranium required several thousand million years, radium sixteen hundred years, the emanation of radium four days, and the 'descendants' of emanation only a few seconds.

Motionless in appearance, matter contained births, collisions, murders and suicides. It contained dramas subjected to implacable fatality: it contained life and death.
Such were the facts which the discovery of radioactivity revealed. Philosophers had only to begin their philosophy all over again and physicists their physics.

After the Nobel Prize in 1903 the production of radium became industrialized and was used in numerous medical researches.
In October 1904 Pierre was named professor at the Faculty of Sciences and in July 1905 he was elected a member of the Academy of Sciences in Paris.

The tragedy — Marie continues alone

On 19th April 1906 Pierre had lunch with his colleagues and then planned to go to the printing house on Rue Gauthier-Villars. It was a rainy day and he found the door closed because of a strike.

[...] Pierre wanted to cross the pavement and reach the other sidewalk. With the sudden movement of an absent-minded man, he abandoned the shelter of the cab, the square box which had been obscuring his horizon, and made a few steps toward the left. But he ran into a fuming beast: one of the horses of the wagon, which was passing the cab at that same second. The space between the two vehicles narrowed dizzily. Surprised, Pierre, in an awkward movement, attempted to hang on to the chest of the animal, which suddenly reared. The scientist's heels slipped on the wet pavement. A cry arose made of a dozen shouts of horror: Pierre had fallen under the powerful horses.

The left back wheel of the wagon hit Pierre's head, he was killed instantly.

[...] It is commonplace to say that a sudden catastrophe may transform a human being forever. Nevertheless, the decisive influence of these minutes upon the character of my mother, upon her destiny and that of her children, cannot be passed over in silence. Marie Curie did not change from a happy young wife to an inconsolable widow. The metamorphosis was less simple and more serious. The interior tumult that lacerated Marie, the nameless horror of her wandering ideas, were too virulent to be expressed in complaints or in confidences. From the moment when those three words, "Pierre is dead," reached her consciousness a cope of solitude and secrecy fell upon her shoulders forever. Mme Curie, on that day in April became not only a widow, but at the same time a pitiful and incurably lonely woman.

After Pierre's death some important questions had to be answered: what would happen with his research, his teaching, his laboratory?

[...] Jacques Curie and Georges Gouy informed the dean of the faculty of their conviction: that Marie was the only French physicist capable of pursuing the work she and Pierre had undertaken. Marie was the only teacher worthy of succeeding Pierre. Marie was the only chief of laboratory who could replace him. Traditions and customs must be swept away so as to name Mme Curie professor at the Sorbonne.

Marie Curie was offered the Chair created by Pierre Curie:

[...] University of France: Mme Pierre Curie, Doctor of Science of Research work in the Faculty of Science of the University of Paris, is charged with a course in physics in the said faculty. [...]This was the first time that a position

in French higher education had been given to a woman. Marie wrote in her diary: "My little Pierre, I want to tell you, too, that I have been named to your chair, and that there have been some imbeciles to congratulate me on it."

[...] For the first time a woman was about to speak at the Sorbonne, a woman who was at the same time a genius and a despairing wife. Here was enough to draw the public of theatrical 'premières', the audience for great occasions.
At noon, at the hour when Marie, standing before the tomb in the cemetery at Sceaux, was speaking in an undertone to him whose succession she assumed today, the crowd had already filled the little graded amphitheater, stopped up the corridors of the Faculty of Science, and overflowed even into the square outside. In the hall, great and ignorant minds were mixed, and Marie's intimate friends were scattered among the indifferent. The worst off were the true students, who had come to listen and to take notes, but had to cling to their seats to keep from being dislodged.
At one twenty-five the noise of conversation grew heavy. There were whisperings and questions; necks were craned so as not to miss any part of Mme Curie's entrance. All those present had the same thought: what would be the new professor's first words, the first words of the only woman the Sorbonne had ever admitted among its masters? Would she thank the Minister, thank the university? Would she speak of Pierre Curie? Yes, undoubtedly: the custom was to begin by pronouncing a eulogy of one's predecessor. But in this case the predecessor was a husband, a working companion. What a strong 'situation'! The moment was thrilling, unique...
Half past one... The door at the back opened, and Marie Curie walked to the chair in a storm of applause. She inclined her head. It was a dry little movement intended as a salute. Standing, with her hands strongly holding onto the long table laden with apparatus, Marie waited for the ova-

tion to cease. It ceased suddenly: before this pale woman, who was trying to compose her face, an unknown emotion silenced the crowd that had come for a show.
Marie stared straight ahead of her and said:
"When one considers the progress that has been made in physics in the past ten years, one is surprised at the advance that has taken place in our ideas concerning electricity and matter..."
Mme Curie had resumed the course at the precise sentence where Pierre Curie had left it.
What was there so poignant in these icy words:"When one considers the progress that has been made in physics..."?
Tears rose to the eyes and fell upon the faces there.
In the same firm, almost monotonous voice, the scientist gave her lesson that day straight to the end. She spoke of the new theories on the structure of electricity, on atomic disintegration, on radioactive substances. Having reached the end of the arid exposition without flinching, she retired by the little door as rapidly as she had come in.

She starts another life

[...] The responsibilities of the 'widowed Mme Curie' would have frightened a robust, happy man. She had to bring up two young children, earn their livelihood and her own, and to fill her place as professor with success. Deprived of the masterly collaboration of Pierre Curie, she had to pursue and carry out the researches undertaken with her companion. Her assistants and students had to receive orders and advice from her. One essential mission also remained: to build a laboratory worthy of Pierre Curie's disappointed dreams, where young research workers could develop the new science of radioactivity.

She was the head of a family. Marie's first care was to give her

daughters and father-in-law a wholesome existence.

[...] This whole-souled worker was haunted by the idea of the overwork to which children were condemned. It seemed to her barbarous to install young beings in ill-ventilated schoolrooms and to steal innumerable sterile 'hours of attendance' from them at the age when they should be running free. She wanted Irène to study very little and very well. How was she to set about it? She reflected, she consulted her friends, professors at the Sorbonne like herself, and like herself, heads of families. Under her impetus was born the original plan of a sort of teaching co-operative, in which great minds would share the task of instructing all their children according to new methods.

[...] An era of excitement and intense amusement opened for some ten little monkeys, boys and girls, who, dispensing with school, went every day to hear one single lesson given by a chosen master. One morning they invaded the laboratory at the Sorbonne where Jean Perrin taught them chemistry. The next day the little battalion moved to Fontenay-aux-Roses: mathematics taught by Paul Langevin. Mmes Perrin and Chavannes, the sculptor Magnou and Professor Mouton taught literature, history, living languages, natural sciences, modeling and drawing. Last of all, in an unused room in the School of Physics, Marie Curie devoted Thursday afternoons to the most elementary course in physics that those walls had ever heard.
Her disciples, some of whom were future scientists, were to retain dazzled memory of these fascinating lessons, of her familiarity and kindness. [...] Marie transmitted her love of science and her taste for work to them. She also taught them the methods which a long career had developed in her. A virtuoso in mental arithmetic, she insisted on having her protégés practice it: "you must get so that you never make a mistake", she insisted, "the secret is not

going too fast." If one of the apprentices created disorder or dirt in constructing an electric pile, Marie grew red in anger. "Don't tell me you will clean it afterward! One must never dirty a table during an experiment."
On the watch for Mme Curie's slightest gesture, the newspapers of the day seized upon these lessons to make merry fun of the intrusion, very discreet and carefully supervised, of the scientists' sons and daughters into official laboratories: "This little company which hardly knows to read or write [said a gossip writer], has permission to make manipulations, to engage in experiments, to construct apparatus and to try reactions... The Sorbonne and the building in the Rue Cuvier have not exploded yet, but all hope is not yet lost."
The collective teaching, fragile as other human enterprises, came to an end after two years.

[...] Were Marie's touching efforts to protect her daughters' personalities from their earliest childhood successful? Yes and no.
[...] Several things, nevertheless, were permanently imprinted upon us: the taste for work – a thousand times more victorious in my sister than in me! – a certain indifference toward money, and an instinct of independence which convinced us both that in any combination of circumstances we should know how to get along without help.

Marie was also a laboratory director and a research worker: She took up the supervision of the laboratory of Pierre. In 1907, the University granted her a laboratory worthy of her merits. The project of the Radium Institute was born out of an association of the heads of university with the director of the Pasteur Institute who foresaw that radioactivity would have applications in biology and in medicine.

[...] Mme Curie had a program of new researches. She per-

formed them in spite of the steady deterioration to her health. She purified a few decigrams of chloride of radium and made a second determination of the atomic weight of the substance. She then undertook the isolation of radium metal [...] finally, Marie, in independent work, discovered a method of measuring radium by the measurement of the emanation it disengaged.

[...] After the fame of the Curie couple, the personal fame of "Mme Curie" mounted and spread like a rocket. Diplomas of doctor honoris causa or of corresponding member of foreign academies arrived by the dozen to encumber the desks at the house in Sceaux, though the laureate never dreamed of putting them in sight or even of drawing up a list of them.

[...] In December the Swedish Academy wishing to recognize the brilliant work accomplished by the woman scientist since her husband's death, awarded her the Nobel Prize in Chemistry for the year 1911. No other laureate, man or woman, had been or was to be judged worthy of receiving such recompense twice.

The citation by the Nobel Committee was "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."

On 6 January 1913 Marie wrote to her niece:

"I have always patiently aimed towards a single goal. I did it although I did not have the least certainty that this was truly right, being aware that life is fleeting and fragile, that is leaves nothing behind, that other beings conceive it in a different way. I did it probably because something compelled me to do so in the same way a caterpillar is compelled

to make its cocoon. This poor caterpillar must begin its cocoon even if it there is no chance to complete it, working with the same care. And if it cannot complete the task, it dies without metamorphosis, without reward.
Let each of us, dear Hania, spin our cocoon, without asking why and to what end."

Between 1913 and the beginning of 1914 the Radium Institute was built in Paris on Rue Pierre Curie, known today as Rue Pierre et Marie Curie. In the same year, a laboratory of radioactivity was opened in Poland. Marie was requested to take up the directorship; she went to Warsaw but accepted only an honorary post. It was also in 1913 that Marie took a vacation in Switzerland with her daughters and a well-known friend, Albert Einstein.

[...] During the summer of 1913 she tried her strength by a walking tour in the Engadines, rucksack on back. Her daughters accompanied her with their governess and the group of excursionists also included the scientist Albert Einstein and his son. A charming 'comradeship of genius' had existed for several years between Mme Curie and Einstein. They admired each other; their friendship was frank and loyal; and sometimes in French, sometimes in German, they loved to pursue interminable palavers in theoretical physics. In the vanguard gamboled the young ones, who were enormously amused by this journey. A little behind, the voluble Einstein, inspired, would expound to his confrere the theories which obsessed him, and which Marie, with her exceptional mathematical culture, was one of the rare persons in Europe to understand. Irène and Eve sometimes caught words on the fly which seemed to them singular. Einstein, preoccupied, passed alongside the crevasses and toiled up the steep rocks without noticing them. Stopping suddenly and seizing Marie's arm, he would exclaim, 'You understand, what I need to know is exactly what happens to the passengers of an elevator

when it falls into emptiness.' Such a touching preoccupation made the younger generation howl with laughter, far from suspecting that the imaginary fall in an elevator posed problems of transcendent 'relativity.'

The war

In July 1914, the 'temple of the future' [as Louis Pasteur called the laboratories], the Radium Institute on Rue Pierre Curie in Paris was at last completed. However, on the 1st of August 1914 the First World War broke out!

Men were mobilized and joined their regiments. Marie made enquiries about the equipment in army hospitals and realized that most of the military hospitals were under equipped in radio diagnostic material. Marie intended to participate in the combat lead by her adopted country. She learned the basics of radiological examination and obtained the necessary radiological equipment. She trained the operators, organized the teams, and in a few months, some twenty units were ready to go to different parts of the front. They were limousines, loaned by benefactors until the end of the war and which once equipped were baptized: "Little Curies." Marie, behind the driving wheel of a car – she had received her driving license – went to the front to direct the installations. She became the directress of radiological services. Her daughter Irène, who was 18 years old at the time, received her diploma as a nurse and joined her. The two women went to the combat zones and made up to twenty or thirty examinations a day; without doubt they were exposed, during the course of their hours of devotion, to an enormous quantity of radiation, the effects of which would be fatal.

[...] She was asked to write a book on Radiology in War: in it she exalted the good work of scientific discovery, eternal research and its human value. She had drawn from her tragic experience new reasons for adoring science.

The story of radiology in war offers a striking example of the unsuspected amplitude that the application of purely scientific discoveries can take under certain conditions.
X rays had had only a limited usefulness up to the time of the war. The great catastrophe which was let loose upon humanity, accumulating its victims in terrifying numbers, brought up by reaction the ardent desire to save everything that could be saved and to exploit every means of sparing and protecting human life.
At once there appeared an effort to make the X ray yield its maximum of service. What had seemed difficult became easy and received an immediate solution. The material and the personnel were multiplied as if by enchantment. All those who did not understand gave in or accepted; those who did not know learned; those who had been indifferent became devoted. Thus the scientific discovery achieved the conquest of its natural field of action. A similar evolution took place in radium therapy, or the medical application of radiations emitted by the radio elements.

What are we to conclude from this unhoped-for development shared between the new radiations revealed to us by science at the end of the nineteenth century? It seems that they must make our confidence in disinterested research more alive and increase our reverence and admiration for it.

It is very nearly impossible to discern in this drily technical little book how important Marie Curie's own initiatives were. What fiendish ingenuity she used to find impersonal formulas, what a rage for effacing herself, for remaining in the shadows! The 'I' was not detestable to Marie it did not exist. Her work seems to have been accomplished by mysterious entities which she names by turn 'the medical organizations' or else 'they', or, in case of extreme necessity 'we'. The discovery of radium itself is dissimulated

among 'the new radiations revealed to us by science at the end of the nineteenth century.' And when she is compelled to speak of herself, Mme Curie attempts to merge into the nameless crowd:
"Having wished, like so many others, to put myself at the service of the national defense during the years we have just traversed, I was at once directed toward radiology."

Marie was in her laboratory when the war ended. It was a double victory for her.

[...] Poland was born again from the ashes and after a century and a half of slavery became a free country once more.

Marie to Joseph Sklodowski, December 1920:

"So now we, 'born in servitude and chained since birth,' we have seen the resurrection of our country which has been our dream. We did not hope to live to this moment ourselves; ...like you, I have faith in the future."

In her Autobiographical Notes *she wrote:*

"Nevertheless, a great joy came to me as a consequence of the victory obtained by the sacrifice of so many human lives. I had lived, though I had scarcely expected it, to see the reparation of more than a century of injustice that had been done to Poland, my native country, and that had kept her in slavery, her territories and people divided among her enemies. It was a deserved resurrection for the Polish nation, which showed herself faithful to her national memories during the long period of oppression, almost without hope. The dream that appeared so difficult to realize, although so dear, became a reality following the storm that swept over Europe. In these new conditions I went to Warsaw and saw my family again, after many years of

separation, in the capital of free Poland. But how difficult are the conditions of life of the new Polish republic, and how complicated is the problem of reorganization after so many years of abnormal life!"

The Radium Institute

After the devastation of the war and the heavy loss of lives, it was difficult to take up the work again. All the scientific laboratories had been affected, including the Radium Institute. Nevertheless, in spite of the difficulties the work had to be done: Irène Curie was now a member of the Radium Institute that became operational in 1918 and would soon be a university centre consecrated to nuclear physics and chemistry.

In 1922 Marie Curie became a member of the Academy of Medicine; she was at the height of her fame. She dedicated her research to the chemical study of radioactive substances and concentrated on the application of these substances in the field of medicine.

Marie understood that it was essential to have a supply of radioactive sources: they were necessary for the treatment of illnesses and indispensable for the progress of research in nuclear physics. Thanks to Marie, the Radium Institute possessed a stock of 1.5 g of radium that contributed to the success of future experiments. This radium was used among other ways for the research of Irène and Fréderic Joliot-Curie, work that prepared the way for the discovery of artificial radioactivity in 1934.

The Radium Institute was the domain of Marie and there reigned a relaxed and informal atmosphere. Marie considered her team as part of her family. As far as the outside world was concerned, she appeared reserved and sometimes a little cold, though she always surrounded her collaborators with a warm encouraging presence. Even when she was suffering with pain and illness, she made the rounds every day and visited each one; she followed their progress and lavished them with advice. She was

Mrs Meloney, Irène, Marie and Eve in the United States, 1921

the first to smile when one of them reached the goal.

Marie's health deteriorated little by little, in spite of her robust constitution. She had to have surgery for a cataract and permanently suffered from buzzing in her ears. As earlier with Pierre and all those who were exposed to too much radiation, Marie had very severe pains. In spite of everything, she carried on and prepared for two trips to the United States that would give her the opportunity to gather the funds necessary for the continuation of her mission...

In America

[...] One morning in May 1920 a lady was ushered into the tiny waiting room of the Institute of Radium. She was called Mrs. William Brown Meloney, and she edited a great magazine in New York.

She had been waiting for this appointment for years. Mrs. Meloney was one of those beings, more and more numerous, whose imaginations were exalted by the life and work of Marie Curie. The scientist represented the highest vision of womanhood to her.

Mrs. Meloney afterward wrote:

"The door opened and I saw a pale, timid little woman in a black cotton dress, with the saddest face I had ever looked upon. Her kind, patient, beautiful face had the detached expression of a scholar. Suddenly, I felt like an intruder. My timidity exceeded her own, I had been a trained interrogator for twenty years, but I could not ask a single question of this gentle woman in a black cotton dress. I tried to explain that American women were interested in her great work, and found myself apologizing for intruding upon her precious time. To put me at my ease Mme Curie began to talk about America.

"America," she said, "has about fifty grams of radium. Four of these are in Baltimore, six in Denver, seven in New

York." She went on naming the location of every grain.
"And in France?" I asked
"My laboratory has hardly more than a gram."
"You have only a gram?"
"I? Oh! I have none. It belongs to my laboratory."
... I suggested royalties on her patents. The revenue from such patents should have made her a very rich woman. Quietly she said:
"Radium was not to enrich anyone. Radium is an element. It belongs to all people."
[...] "What would you like to possess most?" And Mme Curie replied gently: "I need a gram of radium to continue my researches, but I cannot buy it."
Mrs. Meloney conceived of a magnificent plan: she wanted her compatriots to offer a gram of radium to Marie Curie. [...] "Why not to organize a subscription among all the women of America, rich and poor? Nothing is impossible in the United States."
"I myself am no longer young [Marie wrote] and I frequently ask myself whether, in spite of recent efforts of the government aided by some private donations, I shall ever succeed in building up for those who will come after me an Institute of Radium, such as I wish to the memory of Pierre Curie and to the highest interest of humanity.
However, a precious encouragement came to me in the year 1921. On the initiative of a generous daughter of the United States, Mrs. W. B. Meloney, the women of that great American country collected a fund, the "Marie Curie Radium Fund," and offered me the gift of a gram of radium to be placed entirely at my disposal for scientific research. Mrs. Meloney invited me with my daughters to come to America and to receive the gift, or the symbol of it, from the hands of the President of the great republic, at the White House.
The fund was collected by a public subscription, as well by small as by important gifts, and I was very thankful to my

sisters of America for this genuine proof of their affection. So I started for New York at the beginning of May, after a ceremony given in my honor at the Opera of Paris, to greet me before my departing.

I keep a grateful memory of my sojourn in the United States for several weeks, of the impressive reception at the White House, where President Harding addressed me in generous and affectionate words, of my visits to the universities and colleges which welcomed me and bestowed on me their honorary degrees, of the public reunions where I could not but feel the deep sympathy of those who came to meet me and to wish me good luck."

About Marie's reception at the White House Mrs. W. B. Meloney wrote:

On the night before the reception at the White House, at which President Harding was to present the gram of radium to Madame Curie, the Deed or gift was taken to her. It was a beautifully engraved scroll, vesting all rights to a gram of radium, the gift of American women, in Marie Curie.

She read the paper carefully, and then, after a few moments of thought, said: "It is very fine and generous, but it must not be left this way. This gram of radium represents a great deal of money, but more than that, it represents the women of this country. It is not for me; it is for science. I am not well; I may die any day. My daughter Eve is not of legal age, and if I should die it would mean that this radium would go to my estate and would be divided between my daughters. It is not for that purpose. This radium must be consecrated for all time to the use of science. Will you have your lawyer draw a paper which will make this very clear?"

I said that it would be done in a few days.

"It must be done to-night," she said. "Tomorrow I receive the radium, and I might die tomorrow. Too much is at

stake."
And so, late as it was on that hot May evening, after some difficulty, we secured the services of a lawyer, who prepared the paper from a draft Madame Curie herself had written. She signed it before starting for Washington. One of the witnesses was Mrs. Calvin Coolidge. This document read: "In the event of my death I give to the Radium Institute, of Paris, for exclusive use in the Laboratoire Curie, the gram of radium which was given to me by the Executive Committee of Women of the Marie Curie Radium Fund, pursuant to an agreement dated the 19th day of May, 1921."
This act was consistent with the whole life of the discoverer of radium; with the answer she had made to my question a year before:
"Radium is not to enrich any one. It is an element; it is for all people."

Mission accomplished

In this period after the war, Marie Curie became the most famous woman in the world. She was known as the "Mother of Modern Physics", the "Pioneer of the Atomic Age." The success of the application of radiotherapy in the treatment of cancer won her the name "benefactress of humanity." She made numerous trips abroad to advance the cause of the science she had given birth to.

[...] I believe the journey to America had taught my mother something.
It had showed her that the voluntary isolation in which she confined herself was paradoxical. As a student she might shut herself into a garret with her books, and as an isolated research worker might cut herself off from the century and concentrate entirely on her personal work, and indeed she had to do so. But Mme Curie at fifty-five was something

other than a student or a research worker: Marie was responsible for a new science and a new system of therapeutics. The prestige of her name was such that by a single gesture, by the mere act of being present, she could assure the success of some project of general interest that was dear to her. From now on she was to reserve a place in her life for these exchanges and these missions. [...] All her life she had been obsessed by a certain thought: that of the intellectual gifts ignored and wasted in the classes unfavored by fortune. In this peasant or that workman was hidden, perhaps, a writer, a scientist, a painter, a musician... Marie was obliged to limit her activity. She devoted it altogether to the development of international scientific scholarships.
"What is society's interest [she asks in one of her reports]? Should it not favor the development of scientific vocations? Is it, then, rich enough to sacrifice those which are offered? I believe, rather, that the collection of aptitudes required for a genuine scientific vocation is an infinitely precious and delicate thing, a rare treasure which it is criminal and absurd to lose, and over which we must watch with solicitude, so as to give it every chance of fruition."
And finally, paradox of paradoxes! The physicist who had always avoided material profit for herself became the champion of 'scientific property' for her confreres: she wanted to establish a copyright for scientists, so as to reward the disinterested work which serves as a basis for industrial applications. Her dream was thus to find a remedy for the poverty of the laboratories by obtaining subsidies for pure research from the profit of commerce.
Once only, in 1933, she abandoned these practical questions and went to Madrid to preside over a debate on "the Future of Culture": "Don Quixotes of the spirit who are fighting their windmills," Paul Valery, the initiator of the meeting called them. She astonished her colleagues by her courteous authority and by the originality of her interpositions. The members of the congress were filled in alarm,

denouncing the perils of specialization and standardization, and they made science in part responsible for the "crisis of culture" in the world. Here again we see Marie Curie, the most quixotic perhaps of all the Don Quixotes present, defending with the same faith as of old, the love of research and the spirit of adventure and enterprise, in short, the passion which had guided her life always.

"I am among those who think that science has great beauty [she told her interlocutors]. A scientist in his laboratory is not only a technician: he is also a child placed before natural phenomena which impress him like a fairy tale. We should not allow it to be believed that all scientific progress can be reduced to mechanisms, machines, gearings, even though such machinery also has its own 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 and is akin to curiosity..."

The struggle for an international culture, respecting the different national cultures; the defense of personality and talent wherever they are to be found; the struggle to 'strengthen the great spiritual strength of science in the world'; the struggle for 'moral disarmament' and for peace, such were the combats in which Mme Curie engaged, without having the vanity to hope for an early victory.

[...]

Thirty years before, foreboding the death of which hazard was to be the instrument, Pierre Curie had buried himself in work with tragic ardor. Marie, in turn, took up the obscure challenge. Defending herself against the aggression that she feared, she feverishly built round her a rampart of projects and duties. She scorned a fatigue which became more evident every day, and the chronic ills that oppressed her: her bad sight, rheumatism in one shoulder, droning murmurs in her ears.

What did all that amount to? There were other things more important. Marie had just built a factory at Arcueil for the treatment of ores in mass; she had wanted this factory for a long time: she organized the first tests there with enthusiasm. She was preoccupied by the writing of her book, a monument of science which nobody else could write once Mme Curie has disappeared. And the research work on the actinium family was not advancing rapidly enough... She was working with singular haste, and also with the singular imprudence which was usual with her. She had always scorned the precautions which she so severely imposed on her pupils: to manipulate tubes of radioactive bodies with pincers, never to touch unguarded tubes, to use leaden 'bucklers' to ward off the harmful radiations. She barely consented to submit to the blood tests which were the rule at the Institute of Radium. Her blood content was abnormal. What of it? For thirty-five years Mme Curie had handled radium and breathed the emanation of radium. During the four years of the war she had been exposed to the even more dangerous radiation of the Roentgen apparatus. A slight deterioration in the blood, annoying and painful burns on the hands, which sometimes dried up and sometimes suppurated, were not, after all, such very severe punishments for the number of risks she had run!

In the last ten years of her life, Marie had the joy of seeing her daughter Irène and her son-in-law Frédéric Joliot carry out successful research in the laboratory. She lived to see their discovery of artificial radioactivity, but not to hear that they had been awarded the Nobel Prize in Chemistry for it in 1935.

On 6 June 1934, with a persistent fever, Marie had to undergo tests in a clinic. The doctors did not understand the illness that she was suffering from. They sent her to a sanatorium thinking that she had tubercular lesions. She left for the sanatorium at Sancellemoz, in Haute Savoie, facing the Mont Blanc, the highest mountain in the Alps. Her daughter Eve accompanied her, Irène and her hus-

band Fréderic joined them. Marie's condition worsened.

[...] Just the same we perceived the charm, the restrained tenderness and the hidden grace of her we called, in the first line of our letter spotted with ink, stupid little letters which, tied up with confectioners ribbons, Marie kept until her death "darling Mé." "My sweet darling", "my sweet" or else most often "sweet Mé". Sweet, too sweet "Mé" who could hardly be heard, who spoke to us almost timidly, who wanted to be neither feared nor respected nor admired... Sweet Mé who, along the years, neglected completely to apprise us that she was not a mother like every other mother, not a professor crushed under daily tasks, but an exceptional human being, an illustrious woman.

[...] Marie Curie died of leukemia on 4th July 1934.
Science still had to pronounce its verdict over her body. The abnormal symptoms, the blood tests, differing from those in any known case of pernicious anemia, accused the true criminal: radium.
"Madame Curie can be counted among the eventual victims of the radioactive bodies which she and her husband discovered", Professor Regaud wrote.
At Sancellemoz, Dr. Tobé drew up the following report:
"The disease was an aplastic pernicious anemia of rapid, feverish development. The bone marrow did not react, probably because it had been injured by a long accumulation of radiations."
... On Friday, July 6, 1934, at noon, without speeches or processions, without a politician or an official present, Mme Curie modestly took her place in the realm of the dead. She was buried in the cemetery at Sceaux in the presence of her relatives, her friends, and the co-workers who loved her...
A year later the book which Marie had finished before disappearing brought her last message to the young 'lovers of

physics.' At the Radium Institute, where work had been resumed, the enormous volume was added to other scientific works in the light filled library. On the gray cover was the name of the author: "Mme Pierre Curie, Professor at the Sorbonne. Nobel Prize in Physics. Nobel Prize in Chemistry."
The title was made of one severe and radiant word: RADIOACTIVITY.

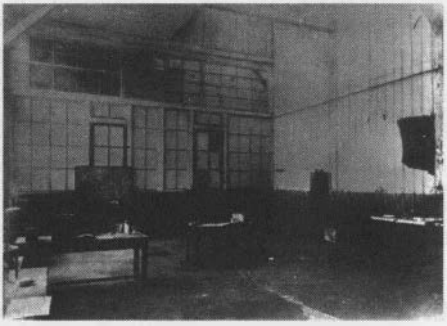
[...] Across the ephemeral movement of one existence, what in Marie Curie was even more than her work or her life: the immovable structure of a character, the stubborn effort of an intelligence, the free immolation of a being that could give all and receive nothing, and above all the quality of a soul in which neither fame nor adversity could change the exceptional purity. Because she had that soul, without the slightest sacrifice Marie Curie rejected money, comfort and the thousand advantages that genuinely great men may obtain from immense fame. She suffered from the part the world wished her to play; her nature was so susceptible and exacting that among all the attitudes suggested by fame she could choose none: neither familiarity, nor mechanical friendliness, deliberate austerity nor showy modesty.
She did not know how to be famous.

Glory again visited Marie in April 1995 —, in the peace of the small cemetery at Sceaux where she rested next to Pierre. On the then French President's initiative, Pierre and Marie's ashes were solemnly transferred to the Panthéon, the French National Mausoleum, where France honors its great men. Marie was the first woman thus honoured, in her own right.

The Panthéon in Paris is located on the Montagne Sainte Geneviève, very near the library where Marie studied during the years of student poverty; it is also close to Rue Pierre et Marie Curie where the Radium Institute stands, and not far from there can still be found the shed where radium was isolated.

With the presence of Pierre and Marie Curie this famous monument became somewhat radioactive, as though glory continued to surround two of the greatest scientists and exceptional human beings with its luminous halo. Marie could not escape the honors this time: the President of the Polish Republic and the President of the Republic of France paid homage to her. The French President reunited Pierre and Marie in the same tribute:

"We admire the splendor of their creations which are the very symbol of a moment in the History of the human mind. In these creations are unified the knowledge of physics, chemistry, biology. In these the great secrets of matter and life are approached, the exploration of which will turn the world upside down."



Pierre and Marie Curie's laboratory

Conclusion

"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

Marie Curie is honored by the whole world as a scientist, one of the greatest of all times, and a pioneer for having paved the way to nuclear physics and cancer therapy. And yet, Marie would not remain in our memories if she would not have been an exceptional human being, faithful to her dreams and ideals, a model for generations to come. She drew her strength from her roots and her anchor points remained unchanged throughout her life: her family, her very close friends, which included all the greatest researchers and scientists of the time, Poland her country of birth, and finally science, the scientific research to which she gave all her energy.

She was humble and modest and offered her life, and the infallible instinct of her genius, to serve humanity.

"A hard and long and dazzling career had not succeeded in making her greater or less, in sanctifying or debasing her, she was on the last day just as gentle, stubborn, timid as in the days of her obscure beginnings. ... this eternal student, of whom Einstein said, "Marie Curie is, of all celebrated beings, the only one whom fame has not corrupted." Passing like a stranger across her own life, intact, natural and very nearly unaware of her astonishing destiny".

— Eve Curie

Appendices

1) The partitions of Poland 1772-1795

The kingdom of Poland had many weaknesses. The nobles elected its kings. The election campaigns to determine who would be king invited domestic and international troubles. Prussia, Austria, France and Russia each repeatedly plotted to put its favorite on the Polish throne. Only nobles were represented in Poland's legislature, the Diet. The Diet rarely accomplished anything because any one member could veto any legislation being considered.

Poland contained large minority groups of various nationalities and religions. The Roman Catholic Poles and their leaders often discriminated against and oppressed the minorities, and sometimes they appealed to Prussia, Austria or Russia for help.

In 1772 these three powers decided to take advantage of Poland's weak condition and seize a slice of Polish territory. This action is known as the First Partition of Poland....

In 1793 Russia and Prussia took a second helping of Polish lands. The rebellion that broke out over this Second Partition was crushed but it brought about the Third Partition in 1795 by Austria, Prussia and Russia. With that, Poland disappeared from the map of Europe until 1919.[1]

1 Extract From 'World History' People and Nations by Anatole G. Mazour, John M. Peoples, HBJ Harcourt Brace Jovanovitch Publishers, Orlando, Florida 1990, page 387.

2) Science laboratory

"If the conquests useful for humanity touch your heart, if you are overwhelmed before the astonishing results of electric telegraphy, of the daguerreotype, of anesthesia, and of other wonderful discoveries, if you are jealous of the part your country may claim in the spreading of these marvelous things, take an interest, I beg of you, in those sacred places to which we give the expressive name of laboratories. Demand that they be multiplied and ornamented, for these are the temples of the future, of wealth, and of well-being. It is in them that humanity grows, fortifies itself, and becomes better. There it may learn to read in the works of nature the story of progress and of universal harmony, even while its own creations are too often those of barbarism, fanaticism, and destruction."[1]

"It is useful to learn how much sacrifice such a life represents. The life of a great scientist in his laboratory is not, as many may think, a peaceful idyll. More often it is a bitter battle with things, with one's surroundings, and above all with oneself. A great discovery does not leap completely achieved from the brain of the scientist, as Minerva sprang, all panoplied, from the head of Jupiter; it is the fruit of accumulated preliminary work. Between the days of fecund productivity are inserted days of uncertainty when nothing seems to succeed, and when even matter itself seems hostile; and it is then that one must hold out against discouragement. Thus without ever forsaking his inexhaustible patience, Pierre Curie used sometimes to say to me: 'It is nevertheless hard, this life that we have chosen.' "[2]

1 Louis Pasteur.
2 Marie Curie, *Autobiographical Notes.*

3) Radioactivity

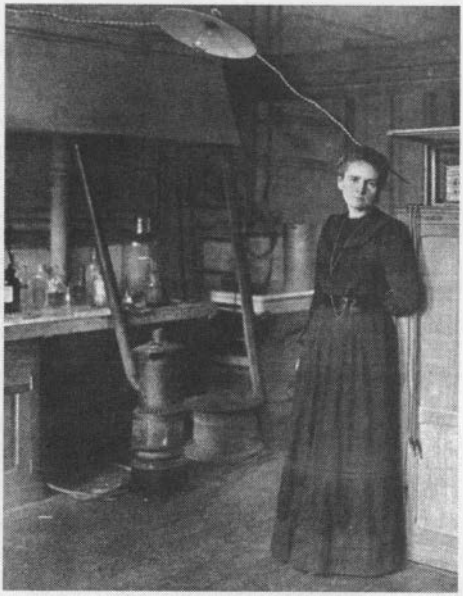
Radioactivity is the emission of energetic particles or waves from atoms. In 1896, Henri Becquerel observed that the first radiation of unknown origin was emitted by uranium salts. Several materials other than uranium were also found to emit these penetrating rays. Materials that emit this kind of radiation are said to be radioactive and to undergo radioactive decay.

The phenomenon of radioactivity is very difficult to observe as it is produced deep within the atom, in its very nucleus. Matter is composed of atoms, most often assembled in molecules. An atom consists of an extremely small, positively charged nucleus surrounded by a cloud of negatively charged electrons. Although typically the nucleus is less than one ten-thousandth the size of the atom, the nucleus contains more than 99.9% of the mass of the atom! Nuclei consist of positively charged protons and electrically neutral neutrons held together by the so-called strong or nuclear force. This force is much stronger than the familiar electrostatic force that binds the electrons to the nucleus, but its range is limited to distances on the order of a few x 10-15 meters.

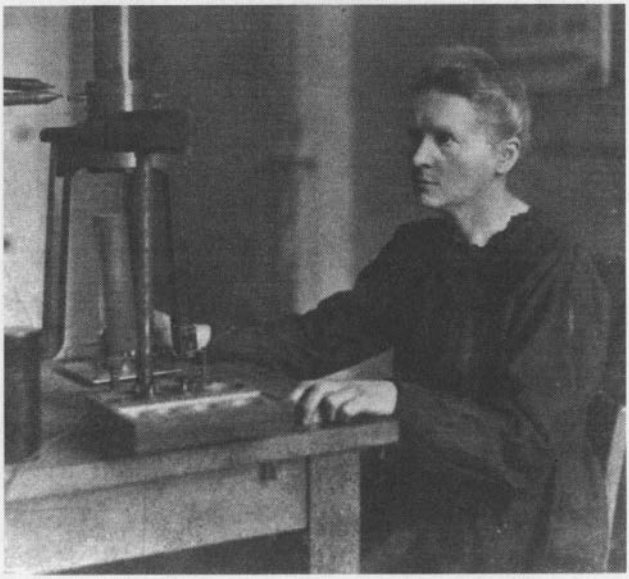
Certain unstable atom nuclei are the source of radiation, designated by the first three letters of the Greek alphabet: alpha (α), beta (β) and gamma (γ). This radiation is composed of particles emitted by high energy nuclei. Alpha radiation is composed of light helium nuclei, β radiation of positive or negative electrons and γ radiation of high energy photons.

If nuclei come close enough together, they can interact with one another through the strong nuclear force, and reactions between the nuclei can occur. As in chemical reactions, nuclear reactions can either be exothermic (i.e. release energy) or endothermic (i.e. require energy input). Two major classes of nuclear reactions are of importance: fusion and fission.

Radioactivity is a natural phenomenon which surrounds us. All



Marie Curie in her laboratory



When Marie was born in 1867, Poland did not exist as an independent nation. Between 1772 and 1795 the entire territory of the Kingdom of Poland was divided between three powerful empires: Prussia, Austria and Russia.

After the first World War, "I had lived, though I had scarcely expected it, to see the reparation of more than a century of injustice that had been done to Poland, my native country..."

the energy we get from the sun comes from one comparatively simple reaction: the fusion of two hydrogen nuclei into another, heavier nucleus. We know that all life on Earth exists because the light generated by the Sun produces food and warms our planet. Therefore, we can say that fusion is the basis for our life This reaction is what has allowed elements other than hydrogen to come into existence. Without it, the great matter factories of the stars would not be able to build the heavier elements that make up our universe.

Without radioactivity, our planet would have frozen over long ago and life on earth would not have been possible. Radioactive processes in the earth's core slowly release the heat essential for our survival, constantly maintaining the temperate climate we take for granted. All life has developed in a constant shower of radiation, adapting to it and occasionally using it for its own benefit.

Our planet is a warm one, but the pleasant conditions we enjoy on its surface are principally due to the radioactive processes taking place at its centre. The earth's radioactivity causes our planet to behave like an immense hot-water bottle, slowing down the cooling rate and consequently making it habitable. The heat necessary for our survival is released by the radioactive disintegrations which take place in the rocks that form our earth's crust.

As with fusion, a great amount of energy can be released in fission. Fission is a nuclear process in which a heavy nucleus splits into two smaller nuclei. The fission of the atom nucleus is a natural phenomenon that releases, at the atom scale, millions times more energy than in the other sources of energies used by mankind. An example of a fission reaction is one that was used in the first atomic bomb and is still used in reactors. Fission is a process that has been occurring in the universe for billions of years. As mentioned above, we have not only used fission to produce energy for nuclear bombs, but we also use fission peacefully everyday to produce energy in nuclear power plants. Interestingly, although the first man-made nuclear reactor was produced only about fifty years ago, the Earth operated a natural fission reactor in a uranium deposit in West Africa about two billion years ago!

Radiation is an omnipresent, inescapable feature of our lives.

Wherever we go we will always be exposed to it. Even our bodies are radioactive, containing as they do millions of atoms of radioactive substances such as potassium.

The large diversity of radioactive elements together with the tremendous spectrum their respective half-lives lead to many applications. Some can survive for billions of years, while others disappear within minutes. This range, from the quasi-permanent to the instantaneous, allows for radioactivity to be used in practically every sphere of human endeavor.

Radioactive sources were what allowed Ernest Rutherford, Marie Curie and others to conduct the first examinations of the nucleus. In the intervening century, radioactivity has revealed itself capable of a myriad of applications, and has become an invaluable source of subatomic information. The very nature of radioactivity allows scientists to trace atoms or molecules with great sensitivity. The discovery of artificial radioactivity in 1934 gave scientists the ability to create radioactive isotopes of any element they wanted. Apart from the countless natural sources of exposure, the harnessing of radiation by humanity has led to a multitude of applications that we use every day. The main artificially generated exposure comes from medical procedures (such as X-rays) but we use radioactive substances and radiations to sterilize food, prolong its shelf life, and prevent fires in public places. However, all these common sources of radiation, whether natural or artificial, remain virtually harmless.

Applications of Radioactivity

One of the more important applications of this technology was the development of radioactive tracers, which have helped to revolutionize biology. Using radioactive tracers, it is now possible to understand the way atoms and molecules move through our bodies. In biological research, short-lived radioactive tracers such as tritium or phosphorus 32 are universally popular. An element such as iodine 123 allows for the examination of thyroid problems with a gamma camera. Those methods have led to a better understanding of the human metabolism and provided an excellent way to verify the effect of drugs

and medication.

The harnessing of radioactivity has also led to the development of one of the most important tools in the medical arsenal. Positron Emission Tomography (also known as PET scanning) gives doctors the ability to film the inner workings of the brain, and to detect cancers in the early stages of development. Such techniques, however, are still expensive, and consequently fairly uncommon. More widespread is the process of 'scintigraphy' – the imaging of gamma radiation with so-called 'gamma cameras'. Scintigraphy scans can be conducted on bones, the thyroid gland, kidneys, lungs, or even on the muscles of the heart. The risks patients face from such radioactive scans are minimal when compared to the benefits such tests can offer.

Another application of Radioactivity relates to our cultural heritage and dating. Carbon 14, with its half-life of 5.700 years, has revolutionized the field of archaeological dating. Using the mathematical laws underlying all radioactive decay, objects and places up to 40.000 years old can be accurately dated. Other radioactive techniques (such as examining the ratio between quantities of potassium and argon present in a sample) can be used to date much older rocks.

Nuclear techniques are used by museographers. Before being exhibited in a museum, the vestiges of past civilisations must be identified and analyzed. The authenticity of the objects is guaranteed by these analyses, which can also supply as much information as possible on their archeological and historical origins.

Here are several examples of application: The ashes which were found in the Chauvet grotto have been analyzed. Their content of carbon-14 has helped to date the period in which the grotto was inhabited by prehistoric men as long as 35000 years ago. A medieval wooden statue was coated with a resin which was hardened by radiation. Thanks to this treatment it can finally be shown to and admired by the public. At the Carnavalet Museum in Paris, Neolithic dugouts found along the banks of the Seine are exposed. One of them was consolidated by radiation, so there is no more risk of it falling to dust. The mummy of a great pharaoh travelled from Cairo to Paris. Before returning to its country it was radiated by gamma rays in

order to destroy all the micro-organisms which were devouring it. The paintings exhibited in the Louvre are not copies. Aglaé, a small accelerator in the Center for research and restoration in French museums, has guaranteed their authenticity.

Radioactivity also has uses in earth science and the study of the environment. It was in these fields that uranium, potassium and rubidium allowed for an accurate estimate of the age of the earth. Climatologists measure solar activity by seeing how much beryllium 10 produced by cosmic rays gets absorbed by the polar ice caps. Oceanographers can, through measuring the abundance of carbon 14 in the oceans, retrace the flows of ancient currents.

Our fear of radiation dates back to the early 20th Century, when many of the early experimenters with radioactivity started to feel the negative consequences of the exposure on their bodies. Much later, in 1945, the use of the atomic bombs on Hiroshima and Nagasaki clarified the enormous risks that a misuse of radioactivity could entail. The 1986 Chernobyl disaster also did much to prejudice us against this powerful natural phenomenon.

Our fear is inextricably tied up with the mysterious and insidious nature of these invisible rays. What is the exact relationship between exposure and future risk? Is there a threshold below which radiation is truly harmless? In all such cases and for all such questions, there is no clear answer. The effects of exposure to radiation depend heavily on the nature of the exposure, which organs were exposed and the general health of the person at the time of the incident.

In order to set up levels permissible for living beings, it is of importance to define doses of exposure which take into account the sensitivity of the whole human body, or in medicine, of a particular organ. This is precisely where radioprotection comes in. Radioprotection is the study of such risks, and the basis of all our attempts to minimize them. Over the last hundred years, the field of radioprotection has devised regulations and safety procedures specifically. The fundamental principle of precaution is that the potential risk may be never zero and that it should be minimized as much as possible.

Nuclear power also generates wastes that are small in volume but highly radioactive and whose management necessitates the greatest

care. Among all the radioactive materials that the ordinary citizen has to be shielded from, the ones that preoccupy him the most are the ones originating from nuclear plants, since they are by far the more radioactive, eclipsing by their activity all the materials coming from hospitals, laboratories and industry. These matters are not ordinary wastes as they contain plutonium, a highly strategic element. The retrieval or not of plutonium is at the core of the management of the spent fuel of reactors. The progresses of waste management are impressive since the not so far away prehistory of nuclear power when radioactive packages were dropped into the sea. The level of the confinement of radioactivity achieved today is quite remarkable and probably already sufficient. Past and ongoing researches aim to reduce further the volume and harmfulness of radioactive matters.

* * *

Marie Curie in her laboratory with husband Pierre

4) Milestones on the path of scientific progress

From 1996 to 1998, the centennial of the discovery of radioactivity was celebrated in France. Expositions were held, meetings took place, films were shown and symposia were organized. The opportunity was also taken to inform the general public of the consequences of this major discovery, the improved understanding of the atomic structure that resulted from it and the improvements to our quality of life that understanding has brought.

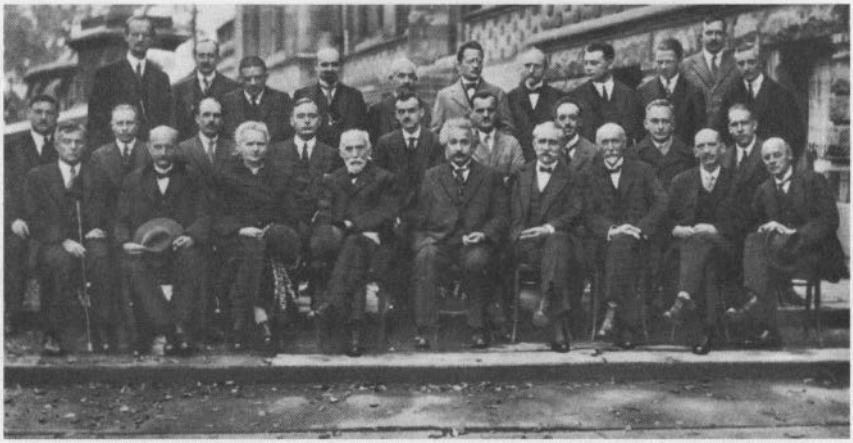
At the turn of the last century and before the discoveries of radioactivity, the atom was an entirely hypothetical concept, whose very existence was doubted in the scientific community.

It was only in 1906 that the French physicist Jean Perrin was conclusively able to demonstrate the existence of the atom. Marie Curie and her husband Pierre had been curious about what was happening inside the atom, and postulated that radioactivity was an atomic phenomenon. In a world where the atom was held to be the fundamental, indivisible unit of matter, the proposal that an atom was capable of decaying or of transforming amounted to heresy.

The following decades saw very many great experimentalists attempting to discover the true nature of the atom. Using the newly-discovered phenomenon of radioactivity, they were able to deduce that an atom consisted of an extremely dense central nucleus surrounded by orbiting electrons. Further experimentation revealed even more fundamental units of matter: the nucleus consists of neutrons and protons bound together very tightly, and both neutrons and protons are comprised of even smaller "quarks". At around the same time, physicists proposed the existence of a particle known as the 'neutrino'for which no direct evidence existed, but whose presence made the physics work. The neutrino would be discovered, exactly as predicted.

All this work being done on the atom revealed the existence of a fundamental force that had previously gone unnoticed before the discovery of beta radioactivity. The weak interaction is seen today as a force that occurs between particles when they exchange 'W' or

'Z' bosons. Experiments at CERN provided in 1982 evidence for these hypothesized particles. The question asked some 80 years ago was finally answered: "Where does radioactivity come from?" In parallel to all of these experimental discoveries, a large number of possible applications of radioactivity were revealed. These ranged across all fields, from the generation of energy to the treatment of cancer to the production of weaponry. The harnessing of the power of radiation is undoubtedly one of humanity's greatest intellectual achievements.[1]



This photograph is from the famous 5th Solvay Conference in Belgium (October 1927), which brought together the greatest minds of the last century including Einstein, Curie, Schroedinger, Bohr, Heisenberg, Planck, Dirac, Pauli, Lorentz, Born, etc.
The majority of the twenty-nine attendees are Nobel Prize winners.
The conference was dedicated to quantum theory.

1 Inspired from www.radioactivity.com

5) Marie's Firsts

Perhaps the most famous of all women scientists, Maria Sklodowska-Curie is notable for her many firsts:

– She was the first to use the term radioactivity for this phenomenon.

– She was the first woman in Europe to receive her doctorate of science.

– In 1903, she became the first woman to win a Nobel Prize for Physics. The award, jointly awarded to Curie, her husband Pierre, and Henri Becquerel, was for the discovery of radioactivity.

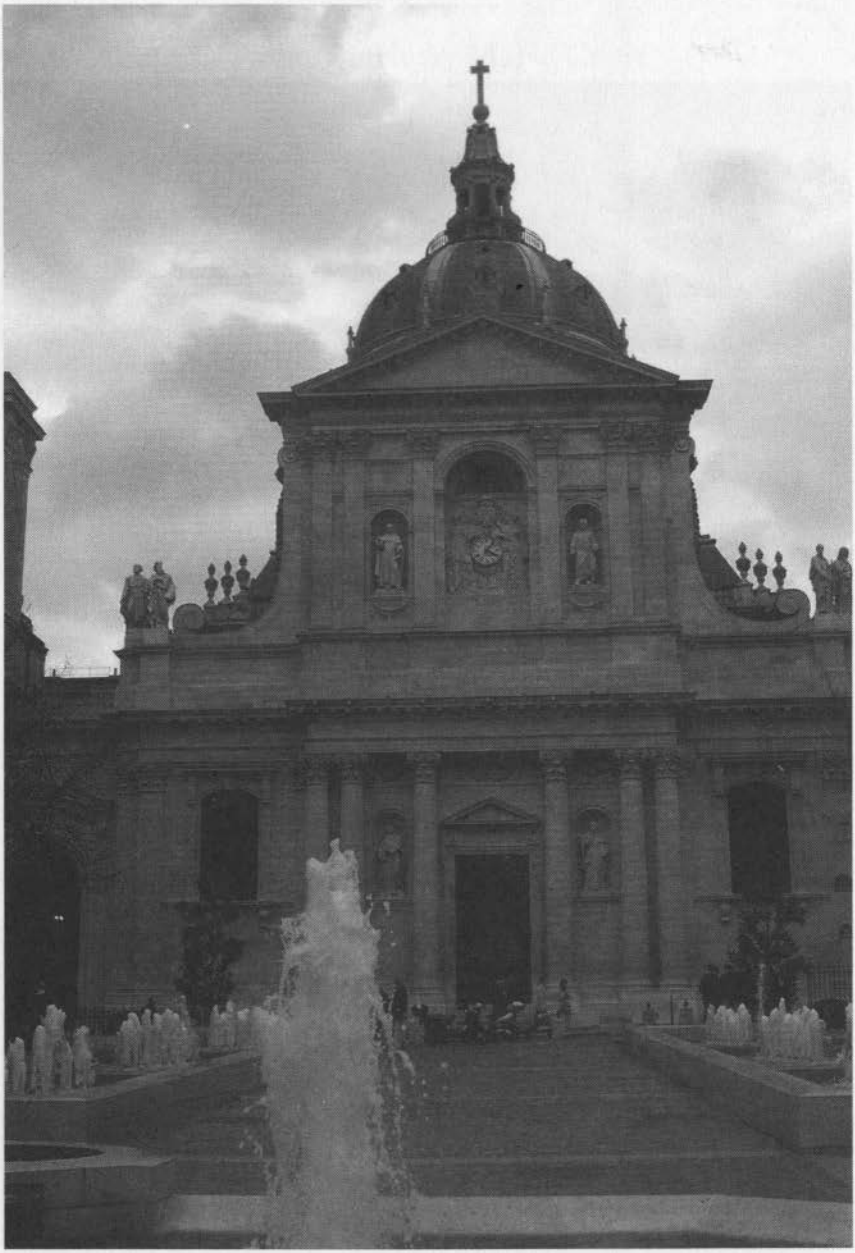
– She was also the first female lecturer, professor and head of Laboratory at the Sorbonne University in Paris (1906).

– In 1911, she won an unprecedented second Nobel Prize (this time in chemistry) for her discovery and isolation of pure radium and radium components. She was the first person ever to receive two Nobel Prizes.

– She was the first mother-Nobel Prize Laureate of a daughter-Nobel Prize Laureate. Her oldest daughter Irène Joliot-Curie also won a Nobel Prize for Chemistry (1935).

– She is the first woman which has been laid to rest under the famous dome of the Pantheon in Paris for her own merits.

– She received 15 gold medals, 19 degrees, and numerous other honors.



La Sorbonne University, Paris

Pierre Curie

6) A Tribute to Pierre Curie by Marie Curie

Pierre, Marie and Irène

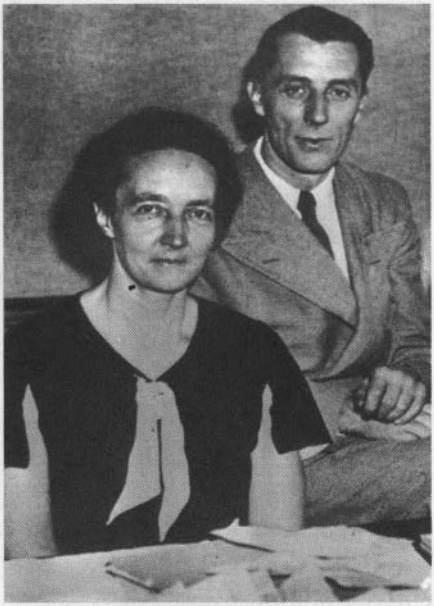
"I have attempted to evoke the image of a man who, inflexibly devoted to the service of his ideal, honored humanity by an existence lived in silence, in the simple grandeur of his genius and his character. He had the faith of those who open new ways. He knew that he had a high mission to fulfill and the mystic dream of his youth pushed him invincibly beyond the usual path of life into a way which he called anti-natural because it signified the renunciation of the pleasures of life. Nevertheless, he resolutely subordinated his thoughts and desires to this dream, adapting himself to it and identifying himself with it more and more completely. Believing only in the pacific might of science and of reason, he lived for the search of truth. Without prejudice or parti pris, he carried the same loyalty into his study of things that he used in his understanding of other men and of himself. Detached from every common passion, seeking neither supremacy nor honors, he had no enemies, even though the effort he had achieved in the control of himself had made of him one of those elect whom we find in advance of their time in all the epochs of civilization. Like them he was able to exercise a profound influence merely by the radiation of his inner strength."

"Marie had never had time to be a perfect educator to her daughters. But Irène and Eve received one gift from her that they will never be able to appreciate enough: the incomparable benefit of living near an exceptional being, exceptional not only in her genius but by her humanity, by her innate refusal of all vulgarity and littleness. Mme Curie avoided even that element of vanity that might most easily have been forgiven her: to let herself be cited as an example to other women."[1]

Eve Curie speaking with Theodore Roosevelt Jr. and Dr. Stecker during the party for the publication of her book *Madame Curie*.

1 Eve Curie

7) Irène Curie (1897-1956)



Frédéric and Irène Joliot Curie

Irène, born in Paris, 12 September, 1897, was the first daughter of Pierre and Marie Curie. She began her studies at the Faculty of Science in Paris and during the First World War she served as a nurse radiographer. She became a Doctor of Science in 1925, and married Frédéric Joliot in 1926. Irène and Frédéric shared years of effort and scientific passion as before them Pierre and Marie Curie. She worked on natural and artificial radioactivity, transmutation of elements, and nuclear physics in collaboration with her husband with whom she shared the Nobel Prize in Chemistry for 1935 in recognition of their synthesis of new radioactive elements.

In 1936 Irène Joliot-Curie was appointed Undersecretary of State for Scientific Research. She became Professor in the Faculty of Science in Paris in 1937. In 1938 her research on the action of neutrons on the heavy elements, was an important step in the discovery of uranium fission.

In 1946 she became Director of the Radium Institute. Being a Commissioner for Atomic Energy for six years, Irène took part in its creation and in the construction of the first French atomic pile (1948). She was involved in the building of the large centre for nuclear physics at Orsay for which she worked out the plans.

She took a keen interest in the social and intellectual advancement of women; she was a member of the National Committee of the Union of French Women and of the World Peace Council. She was a

member of several foreign academies and of numerous scientific societies, had honorary doctor's degrees from several universities, and was an Officer of the Legion of Honour.

Irène died in Paris in 1956. Frédéric and Irène Joliot-Curie had one daughter, Hélène, born in 1927, and one son, Pierre, born in 1932. Pierre is a biochemist. Hélène is a nuclear physicist and professor at the University in Paris; she married Paul Langevin's grand-son: Michel Langevin (1926-1985) who was a physician; their son Yves Langevin is an astrophysicist. (Paul Langevin was a French physicist who worked with Pierre Curie.)[1]

8) Eve Curie (1904-2007)

Eve Curie was born in Paris on 6th December 1904 as Pierre and Marie Curie's youngest child. She was a gifted musician as was her grandmother Bronislawa, Marie Curie's mother. Marie always encouraged her to develop her skill and she first had a career as a concert pianist. Later on she became a writer and a journalist during World War II.

The biography she wrote after her mother's death was a best seller in 80 countries. She married Henri Labouisse (1904-1987), a diplomat who became President of UNICEF and was awarded the Nobel Peace Prize in 1965. Eve Curie lived in New York where she died on October 26th 2007 at the age of 103. She used to say while joking: "I am the shame of my family. There were five Nobel Prize among mine, my mother got two, my father one, my sister and her husband one, even my husband had one, and it has only me there who did not receive any!"

* * *

1 Excerpted from *Nobel Lectures, Chemistry* 1922-1941, Elsevier Publishing Company, Amsterdam, 1966 .

9) Chronology

1859, May 15	Birth of Pierre Curie in Paris.
1867, Nov. 7	Birth of Marya Sklodowska in Warsaw.
1891, Nov.	Marie arrived in Paris.
1895, July	Pierre Curie married Marie Sklodowska.
1895, Nov.	Discovery of X-rays by Wilhelm C. Roentgen in Germany. With radiography it was possible for the first time to look inside the human body
1896	At the Museum of Natural History, Henri Becquerel discovered that the element uranium emits penetrating radiation (natural radioactivity).
1896, July	First treatment of cancer using X-rays.
1897	J.J. Thomson characterized the electron by measuring its speed and charge-to-mass ratio, and showed that all atoms contain electrons.
1897, Sept. 12	Birth of Irène Curie, first daughter of Pierre and Marie.
1898	Pierre and Marie Curie discovered polonium (July) and radium (December) at the School of Industrial Physics and Chemistry (EPCI) in Paris. Marie Curie coined the term radioactivity.
1899	Several scientists demonstrated that uranium emits two types of radiation. In January, Ernest Rutherford called them respectively a and ß radiation. On 6 November, Pierre and Marie Curie published a paper in which they reported a singular property of radium: "induced radioactivity".
1900, March 19	Birth of Frédéric Joliot
1901-1904	Jean Perrin (and independently Hantaro Nagaoka) assumed that the atom had a structure reminding to that of the solar system.

1901-1903	Ernest Rutherford and Frederic Soddy demonstrated the "period" (according to the law of radioactive decay) that characterizes each radioactive element. They showed that radioactivity is the transmutation of one element into another.
1903, Dec.	Pierre and Marie Curie were awarded the Nobel Prize in Physics with the French scientist Henri Becquerel.
1904	Pierre Curie became a professor at the University of the Sorbonne.
1905	Recognition of the beneficial action of radium rays in treating tumors. Birth of Curie therapy.
1906, April 19	Pierre Curie died in an accident.
1906, Nov.	Marie Curie became the first woman to teach at the Sorbonne. Ernest Rutherford identified a radiation as a helium particle.
1909	Decision taken to build the Radium Institute.
1910	Marie Curie isolated metallic radium and determined its atomic mass.
1911	Frederic Soddy established the existence of isotopes. Ernest Rutherford demonstrated the presence of a nucleus at the center of the atom. Marie Curie was awarded the Nobel Prize in Chemistry.
1913	Niels Bohr worked out a model of the atom in which electrons orbit the nucleus.
1914-1918	First World War. Marie Curie equipped vehicles with radiology equipment, called 'Little Curies", for treatment of the wounded at the warfront.
1919	Ernest Rutherford performed the first artificial nuclear transmutation, by transforming nitrogen into oxygen through particle bombardment. Opening of the Radium Institute in Paris.
1920	Creation of the Curie Foundation.
1924	Frédéric Joliot works as Marie Curie's assistant at the Radium Institute. He will marry Irène Curie in 1926.

Curie Museum: Located at the Curie Institute in Paris, this museum was housed in the same laboratory where Marie worked up to her death.

Pierre and Marie Curie University: name of one of the faculties of Sciences of Paris.

Maria Curie-Sklodowska University: name of a public university in Lublin, Poland.

Station Pierre et Marie Curie: name of a Paris metro station.

French postal stamp (1938)
The inscription reads: Pierre and Marie Curie discover radium, Nov. 1898.
International Union Against Cancer

1930	Ernest Lawrence built the first cyclotron at Berkeley.
1932	James Chadwick demonstrated the existence of the neutron.
1934	Frédéric and Irène Joliot-Curie discovered artificial radioactivity. A radioactive element was created for the first time. The discovery of artificial radioactivity heralded the emergence of nuclear medicine.
1934, July 4	Marie Curie died from leukemia.
1935	Irène and Frédéric Joliot-Curie awarded the Nobel Prize in Chemistry for the discovery of radioactivity.
1936	Opening of the Curie Foundation hospital in Paris.
1938:	Otto Hahn and Fritz Strassmann reported the fission of uranium.
1939	Frédéric Joliot, Hans Halban, Lew Kowarski and Francis Perrin demonstrated the possibility of the chain reaction and therefore of its energy applications. They showed that fission is accompanied by great release of energy and by the emission of neutrons which can break open other uranium nuclei, and so on.
1956	Irène Curie died from leukemia.
1958	Frédéric Joliot-Curie died in Paris.

* * *

10) Curie dictionary

Curie: (symbol Ci) is the old standard unit for measuring the activity of a given radioactive sample. It is equivalent to the activity of 1 gram of radium.

Curiethérapie: medical application of the use of radium in radiation therapy.

Little Curies or Petites Curies: During the First World War in 1914, to avoid transporting the wounded away from the front, Marie Curie outfitted cars. About 200 vehicles were equipped with X-ray equipment and sometimes with a generator. At the battle-front, in makeshift hospitals with the help of X-ray examinations, doctors were able to locate bullets and shells. In this way approximatively one million examinations were conducted. It was the first medical imagery service in France.

Curium: a synthetic radioactive chemical element with the atomic number 96, discovered in 1944, named after Pierre and Marie Curie.

Curite: radioactive mineral named after Pierre Curie.

Sklodowskite and Cuprosklodowskite: radioactive elements named after Marie Sklodowska-Curie.

Curie Institute or Institut Curie: a world center in Paris for the study of radioactivity, one of the most prestigious research institutions for research on and treatment of cancer.

Marie Curie Fellowship Association: association of scientists (Marie Curie Fellows) who were awarded mobility research training grants by the European Community.

Curie Museum: Located at the Curie Institute in Paris, this museum was housed in the same laboratory where Marie worked up to her death.

Pierre and Marie Curie University: name of one of the faculties of Sciences of Paris.

Maria Curie-Sklodowska University: name of a public university in Lublin, Poland.

Station Pierre et Marie Curie: name of a Paris metro station.

French postal stamp (1938)
The inscription reads: Pierre and Marie Curie discover radium, Nov. 1898.
International Union Against Cancer

11) General notes

Atom: The smallest component of matter which cannot be broken down by any chemical means. A typical atom consists of a nucleus of protons and neutrons with electrons circling this nucleus.

Claude Bernard (1813-1878): French physiologist who defined the fundamental principles of scientific research in his treatise: An introduction to the Study of Experimental Medicine.

Auguste Comte (1798-1857): French philosopher, who was considered as one of the founders of sociology (the study of human social behavior). His school of thought, Positivism, was influential towards the end of the 19th century. Positivism holds that the only authentic knowledge is that based on actual sense experience.

Cyclotron: A type of particle accelerator. A cyclotron accelerates charged subatomic particles (protons, electrons) greatly increasing their energy.

Charles Darwin (1809-1882): British naturalist and biologist, author of a theory of organic evolution claiming that new species arise and are perpetuated by natural selection, known by the name of Darwinism.

Don Quixote: Tragicomic hero of a Cervantes novel. Don Quixote's main quest in life is to revive chivalric virtues and values. Honest and idealistic, he wants to save the world and dispense justice. He is the symbol of an absurd dreamer living in his own world.

Isotope: One or two or more atoms having the same atomic number but different mass numbers. Isotopes are different forms of a

single element. For example, Carbon 12 and Carbon 14 are both isotopes of carbon, one with 6 neutrons and one with 8 neutrons but both with 6 protons.

Alfred Nobel (1833-1896): Chemist, engineer, inventor of dynamite and manufacturer of explosives. Born in Sweden. When his brother died, a French journalist published his obituary by mistake and called him a 'merchant of death'. Realizing the disaster that his inventions were causing, Alfred Nobel wrote his last will and testament and established the Nobel Foundation to administrate the Nobel Prizes. Every year since 1901, in physics, chemistry, medicine, literature and work for peace, men and women, without distinction of nationality are recognized for their outstanding contributions in their field of work.

Louis Pasteur (1822-1895): French chemist and biologist. His most celebrated work was related to the discovery of a method, pasteurization, for the preservation of food. By this method, harmful microorganisms are destroyed with high temperature without any major changes in the chemistry of the food. He produced the first vaccine against rabies.

Pantheon: Monument in Paris. Originally a church, it became a burial place for famous French heroes. The inscription above the entrance reads: "Aux grands hommes, la patrie reconnaissante" ("To its great men, the grateful homeland.") The absence of a verb in French emphasizes that the implicit notion of honour is given *from* the homeland to the great men. By burying its great men in the Pantheon, the nation acknowledges the honor it received from them.

Oswald Spencer (1820-1903): British philosopher and sociologist, who was one of the principal proponents of evolutionary theory in the mid-nineteenth century. At the time, his reputation rivaled that of Charles Darwin.

Radioactivity: name given by Marie Curie, in 1898, to the atomic property of certain heavy elements which spontaneously emit radiation; this property is persistent in all physical and chemical states of matter.

The discovery of radioactivity brought several means to study the constitution of the atom and atomic nucleus. Today, radioactivity and X-rays are employed in medicine in general, in archaeology, geology, in the restoration of art works and for food conservation.

Tsar or Czar: Russian imperial title in use until the revolution in 1917, derived from the Latin *Caesar*, the title of Roman Emperor.

X-Rays: One century ago, Wilhelm Konrad Roentgen discovered the X-ray (so called because at that time no one knew what this was) which began the use of energy to visualize medical problems in patients. The subspecialty of medicine which developed from this discovery is Radiology. With X-rays both then and now, the rays themselves (a form of energy) are not visible with the eye. Another method or material must be used to convert the information to a visible or useable form. X-rays typically use film or screens combined with TV to make the structures penetrated by ray visible.[1]

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1 From www.uhrad.com/kids.htm

12) Suggestions for further reading

— Curie, Eve. *Madame Curie*. Translated by Vincent Sheean. 1937. Reprint, New York: Da Capo, 1986.
— Curie, Marie. *Pierre Curie*. Translated by Charlotte and Vernon Kellogg. New York: Macmillan, 1932. (Marie Curie's *Autobiographical Notes* are included at the end of *Pierre Curie*.)
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— McGrayne, Sharon Bertsch. *Nobel Prize Women in Science: Their Lives, Struggles, and Momentous Discoveries.* New York: Carol Press, 1998.
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— Quinn, Susan. *Marie Curie: A Life*. New York: Simon & Schuster, 1995.
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The life of Marie Curie contains prodigies in such number that one would like to tell her story like a legend. She was a woman; she belonged to an oppressed nation; she was poor; she was beautiful. A powerful vocation summoned her from her motherland, Poland, to study in Paris, where she lived through years of poverty and solitude. There she met a man whose genius was akin to hers. She married him; their happiness was unique. By the most desperate and arid effort they discovered a magic element, radium. This discovery not only gave birth to a new science and a new philosophy: it provided mankind with the means of treating a dreadful disease.

Marie Curie lives in our memory as an exceptional person: one who was fired up by the ideals of justice, peace and social progress. She had the genius of discovery, the intuition that science could open the doors of a new world. Among scientists and geniuses, Marie Curie remains a legendary figure, a unique example of grandeur of soul and simplicity of heart.

Indeed, Marie Curie was a discoverer and therefore, an illuminator. She is also an example of a heroic adventurer, since she pursued her mission, despite all difficulties and calamities. As a servant of humanity, she was also a harmoniser and a benevolent soldier in the march of human progress.

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