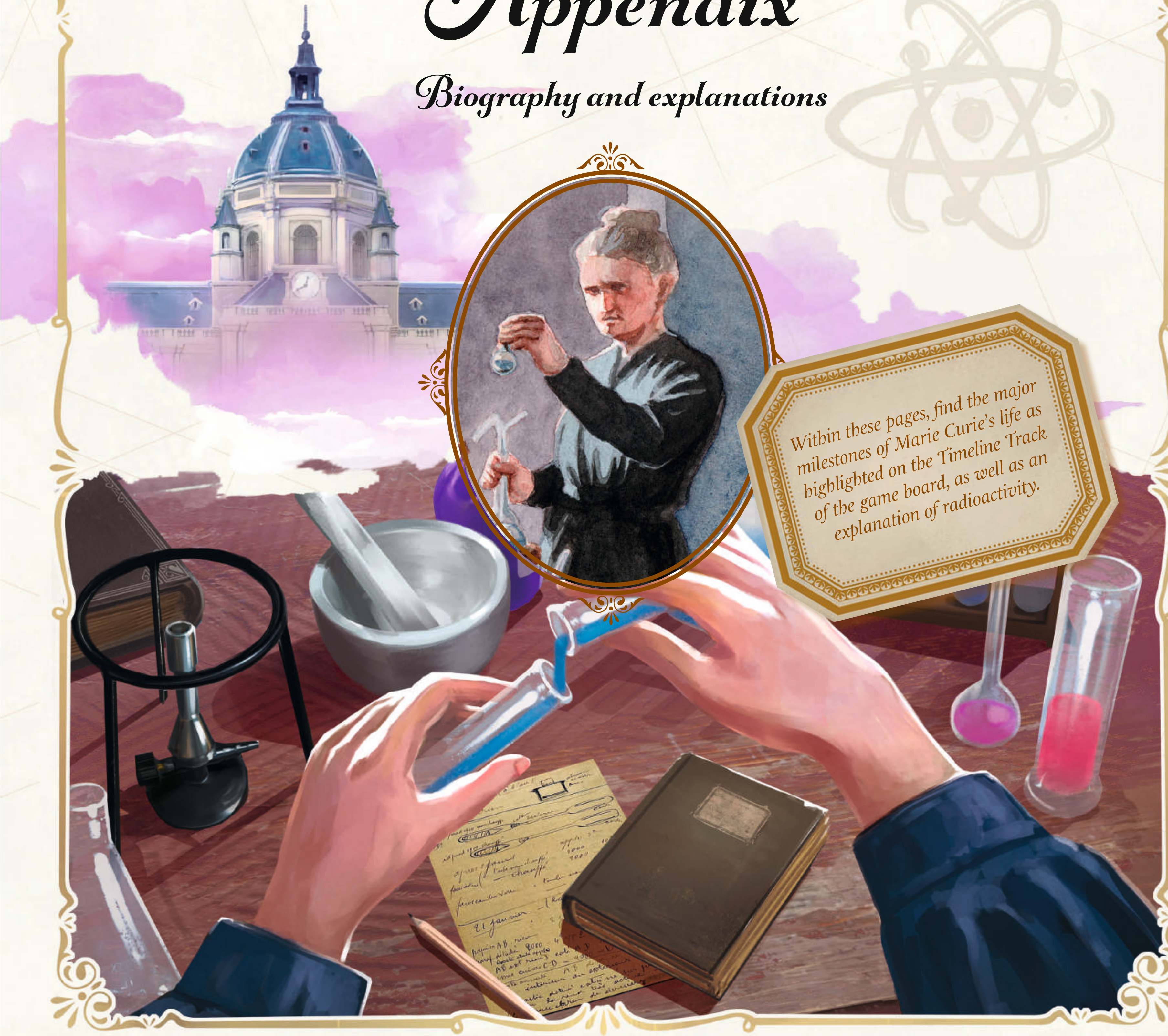
Appendix

Biography and explanations



Within these pages, find the major milestones of Marie Curie's life as highlighted on the Timeline Track of the game board, as well as an explanation of radioactivity.

Marie Curie's Biography

"First principle: never let oneself be defeated by people or by events."

1903 Nobel Prize Portrait.
(Nobel foundation, public domain)

Marie Curie, born Maria Salomea Skłodowska, is a scientist with an exceptional destiny who fought all her life to be able to carry out her experiments and make a place for herself in a field that was at the time reserved to men. Her life is one of a fighter, and her work has changed the face of the world. This is her story.

1867 - Birth

Maria Salomea Sklodowska was born on November 7th, 1867 in Warsaw, in a part of Poland then under Russian control, where the Polish language was banned.

She came from a noble, patriotic, and educated family, with a father who was a professor of physics and mathematics and a mother who was a teacher.

They did not hesitate to enroll their children in schools where they could clandestinely study Polish.

Maria and her sisters, Bronia and Helena, with their father Wladyslaw Skłodowski
(Unknown photographer, public domain)

1883 - Gold Medal at School

Following the deaths of her mother and of her eldest sister from illness, Maria took refuge in her studies where she excelled. For her secondary school diploma, she received a gold medal.

However, she could not continue her education since universities were forbidden to women in her country. Maria and her sister Bronia then made a pact: both would go to study in Paris. While her sister Bronia went first to study medicine, Maria stayed in Warsaw to work as a governess to support both of them and save money for her future studies.

Maria Sklodowska in 1888
(Photo library Hachette Livre)

"Life is not easy for any of us. But what of that? We must be perseverant and, above all, have confidence in ourselves. We must believe that we are gifted for something, and that this thing, at whatever cost, must be attained."
Marie Curie

1891 - Arrival in Paris

In November 1891, Maria finally arrived in Paris at the age of 24 and enrolled at the University of La Sorbonne to continue her studies, as she wished.

1893 - Degree in Physical Sciences

Maria, who was very hardworking, obtained her degree in Physical Sciences with honors and finished first of her class. At the time, there were only about 3% of women in the Faculty of Sciences at La Sorbonne.

"In life, nothing is to be feared, everything is to be understood."
Marie Curie

1894 - Meeting Pierre Curie

While working on the magnetic properties of various steels under somewhat Spartan conditions, Maria met Pierre Curie, a physicist known for his work on magnetism and piezoelectricity, who was also a professor at the Municipal School of Industrial Physics and Chemistry of Paris. They began to collaborate, and this meeting changed the course of their lives.

That year, Maria also obtained a degree in Mathematical Sciences and finished second of her class.

"You cannot hope to build a better world without improving the individuals."
Marie Curie

1895 - Marriage to Pierre Curie

Maria decided to return to her native country to reunite with her family and teach as she had always wished. Pierre Curie, in love with the young woman, asked her to come back and become his wife. The couple married in Sceaux on July 26, 1895. She then became Marie Curie.

"When you receive this letter, your Maria will have changed her name. When you receive this letter, write to me as: Madame Curie. School of Physics and Chemistry, 42, rue Lhomond. That is what I will be called from now on."
Marie Curie to her friend Kazia

Pierre and Marie Curie at their wedding in 1895.
(Photo library Hachette Livre)

"It's always good to marry your best friend."
Marie Curie

1896 - First in the Agrégation

Marie Curie came first in the *agrégation** to teach mathematics. However, she decided to continue her studies with a doctoral thesis.

1897 - Doctoral Thesis in Physics

On September 12, 1897, Marie Curie gave birth to her first daughter, Irène.

The same year, she defended her doctoral thesis in physics on the "uranic rays" discovered by Henri Becquerel in 1896. While he was conducting research on the fluorescence of uranium salts, he concluded that uranium spontaneously emitted radiation.
Thanks to an instrument developed by her husband Pierre and her brother-in-law Jacques Curie – the piezoelectric quartz – she obtained surprising results suggesting that uranium ore contained an unknown element, far more active than uranium. It was the beginning of a research that would change the world.

"I am among those who think that science has great beauty. A scientist in his laboratory is not only a technician: he is also a child placed before natural phenomena that impress him like fairy tales." ***Marie Curie***

** most competitive and prestigious examination for civil service in the French public education system*

1898 - Discovery of Polonium and Radium

Pierre Curie set aside his own research to join Marie Curie in her study of radiation.

Thanks to Baron Henri de Rothschild's financial support, they imported several tons of pitchblende, the primary uranium ore, from Bohemia. By refining this ore, they managed to isolate not one, but two new elements present in very small quantities: polonium (named in honor of Poland) on July 18th; and radium on December 26th, 1898.

The spontaneous radiation of these elements – their radioactivity, a term coined by Marie Curie – is of the same nature as that of uranium but much more intense. For example, polonium would be 400 times more radioactive than uranium.

1902 - Obtaining a Decigram of Pure Radium Chloride

Pierre and Marie Curie spared no effort and worked tirelessly despite difficult working conditions and basic comfort.

After processing several tons of uranium ore, they finally managed to obtain a decigram of radium chloride, which allowed them to measure the atomic weight of radium and to identify the position of this element in the Mendeleev periodic table (a table for the classification of chemical elements).
Even though they barely had enough money to buy uranium ore minerals, Marie and Pierre Curie refused to file a patent to profit from their discoveries. On the contrary, they made their research available to as many people as possible – both researchers and industrialists – considering it could be a major advancement for humanity.

"Radium should enrich no one. It's an element. It belongs to everyone."
Marie Curie

1903 - Nobel Prize in Physics

Marie Curie defended her doctoral thesis on rare radioactive substances before the Faculty of Sciences at the University of Paris and received the distinction "très honorable" (very honorable).

That same year, she was jointly awarded the Nobel Prize in Physics with Pierre Curie and Henri Becquerel for their discovery of natural radioactivity. She became the first woman to receive a Nobel Prize.

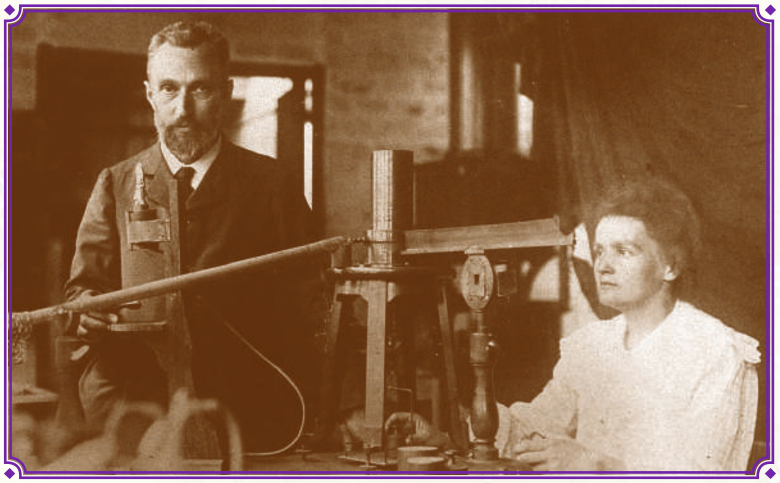
In the archives of the Nobel Committee, it was discovered that the nomination submitted by the French Academy of Sciences only included the names of Henri Becquerel and Pierre Curie. A Swedish academician became aware of this and informed Pierre Curie, who intervened to have Marie's name added.

In addition to the Nobel Prize, Marie Curie shared with her husband the Davy Medal, a scientific distinction awarded by the Royal Society of London (the British equivalent of the Academy of Sciences), for their work on radium. She was again the first woman to receive it.

When a journalist once asked her, "What does it feel like to be married to a great scientist?" She replied, "You'll have to ask my husband."

1904 - Radium in Fashion

In October 1904, Pierre Curie was appointed professor of a new chair of physics at La Sorbonne. This position came with a small laboratory in an annex of the university, with Marie Curie named as the director of research.



Pierre and Marie Curie in their laboratory around 1904. (Unknown photographer, public domain)

On December 6th, 1904, Marie gave birth to the couple's second daughter, Eve.

While radium had been used in clinical trials for the treatment of serious diseases, such as cancer, the belief spread that low-dose exposure could be beneficial to health.

Radium then became a worldwide fad, considered a new magic potion that could cure all ailments. This led to the development of an industry, for its extraction and also for its use in various sectors. At that time, one could buy radium matches, rejuvenating creams, cigarettes, toothpaste, baby powder, and even radium fountains to drink radioactive water…

In France, the company Tho-Radia sold a radium-based beauty cream in pharmacies, prescribed by a so-called Dr. Alfred Curie who never existed. Containing small quantities of radium, it was supposed to erase facial wrinkles. Its slogan: "Science has created THO-RADIA to beautify women. For them to enjoy it. Who wants to remain ugly!" Fortunately, a gram of radium costed a fortune at the time. Most products touting its virtues contained only tiny quantities, probably tiny enough to remain harmless.

However, in the 1920s, the marketing of supposed radium-containing remedies caused numerous victims, especially in the United States. The most notorious case was that of Eben Byers, a steel magnate who died from radiation poisoning in 1932 after losing his jaw. Between 1927 and 1930, he drank nearly 1,400 bottles of Radithor, water containing radium salts, touted as a miracle cure with energizing properties.

Awareness of the dangers of radium began to emerge, but it was not until 1937 that it was banned for non-medical usages. It continued to be used until the late 1950s for its photoluminescent properties before being finally abandoned and replaced by other elements in radiotherapy.

Marie Curie in her laboratory at the School of Physics and Chemistry around 1905 (Photo library Hachette Livre)

1906 - Professor at La Sorbonne

On April 19th, 1906, Pierre Curie died accidentally, struck by a horse-drawn vehicle. Deeply affected by this death, Marie, now a widow with two children to support, continued her work regardless, thanks to the support of her close ones.

She replaced her husband in the chair of physics. On November 5th, 1906, numerous journalists, artists, political figures, and women of the high-society attended her first lecture.

Le Journal wrote:

"It is […] a great feminist victory that we celebrate today. For, if women are admitted to provide higher education to students of both sexes, where will henceforth lie the so-called male superiority? Truly, I tell you: the time is near when women will become human beings."

Marie Curie became the official holder of the chair, now titled "general physics and radioactivity," on November 16th, 1908, thus becoming the first female professor at La Sorbonne and in all French universities.

1910 - Extraction of a Gram of Pure Radium

Marie Curie managed to isolate a gram of radium in its pure metallic form and published the *Treatise on Radioactivity*, a foundational work of this new science. It took her an average of 3 tons of pitchblende to obtain a gram of radium.

1911 - Nobel Prize in Chemistry

Marie Curie received the Nobel Prize in Chemistry awarded by the Stockholm Academy of Sciences for her work on radium and polonium. In her speech, she emphasized the importance of Pierre Curie's work in her results, just as he had done for her during his speech for the first Nobel Prize.

"The chemical work aimed at isolating radium in the form of pure salt and characterizing it as a new element was carried out especially by me, but is intimately linked to the joint work."
Marie Curie

Marie Curie is not only the first woman to have received the Nobel Prize, but also the only woman to have received two, and the only person to have been honored in two distinct scientific fields (Physics and Chemistry).

Marie Curie then played a role in the creation of the Radium Institute, a research center in physics and chemistry at number 1 in the newly named "rue Pierre Curie" (renamed in 1967 to "rue Pierre et Marie Curie"), in the 5th arrondissement of Paris. Within the Radium

Institute, two laboratories coexisted: the physics and chemistry laboratory of Marie Curie and the biology laboratory of Dr. Claudius Regaud, focused on radiotherapy and cancer therapy research. The construction of the Institute was completed in 1914 on the eve of World War I.

1914 - On the War Front

The outbreak of World War I led to the temporary closure of the newly inaugurated Radium Institute in July. Marie Curie mobilized and decided to put her knowledge to the service of the wounded.

She donated a portion of her savings, including the money from her second Nobel Prize, to support the war effort.

She even went as far as to donate her Nobel Prize gold medals to be melted down at the Bank of France, which the official refused to do.

With the help of the Red Cross, she developed eighteen mobile surgical units. These radiology vehicles (later nicknamed «Les P'tites Curies» - Little Curies), could go very close to the battlefields and enabled precise localization of shrapnel or bullets to facilitate surgical operations.

It is estimated that these units saved the lives of a million soldiers. Marie Curie also contributed to training young women in radiology to assist front-line surgeons. She regularly went to the field to perform radiographs, as did her daughter Irène, who became a Red Cross nurse at 17.

1921 - Trip to the USA

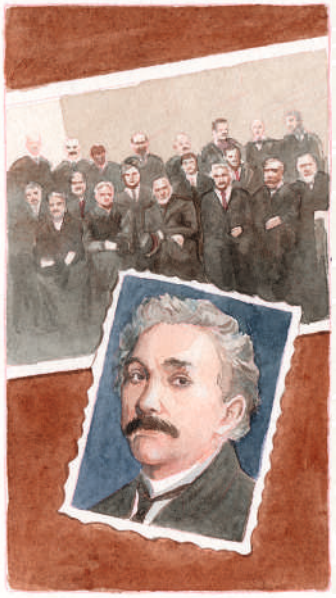
After the war, research at the Radium Institute struggled to resume due to a lack of resources in a country devastated and in the midst of reconstruction. Marie Curie received the support of an American benefactor and journalist, Mrs. Meloney. Fascinated by Marie Curie, she organized a fundraising campaign among American women to enable her to buy a gram of radium from the Pittsburgh factory, where the processes she had developed were being applied industrially. Marie Curie traveled to the United States, accompanied by her two daughters, to receive a gram of radium from President Warren Harding at the White House, as well as numerous instruments and significant sums of money. This trip had a considerable impact.

The Curie Foundation, created by the two leaders of the Radium Institute (Marie Curie and Claudius Regaud) a year earlier in 1920, developed to fund research work and enabled the application of discoveries on radioactivity to cancer treatment.

"I have learned that the way of progress was neither swift nor easy."
Marie Curie

1925 - Reunion with Albert Einstein

It was in Geneva that Marie Curie met again with Albert Einstein, with whom she was involved in the International Committee on Intellectual Cooperation created by the League of Nations (the precursor to the United Nations), for science and for peace.



They had first met in 1911 at the Solvay Congress in Brussels, bringing together the world's leading scientists in the field of physics. Among the 24 attendees, Marie Curie was the only woman. In 1927, at the 5th Solvay Congress, the most famous one, Marie Curie was still the only woman among the twenty-nine personalities. Moreover, seventeen of these scientists had received or would receive a Nobel Prize.

1934 - Death of Marie Curie

On July 4th, 1934 in Passy, Marie Curie passed away at the age of 66 due to aplastic anemia caused by prolonged exposure to radiation throughout her years of research. Additionally, Marie Curie also kept a sample of radium on her bedside table as a night light.

1995 - Transfer to the Panthéon

The Panthéon is an emblematic monument in Paris which houses the remains of distinguished French citizens including writers, scientists, philosophers, and political figures.

On April 20th, 1995, her ashes, along with those of her husband, were transferred to the Panthéon in Paris, encased in lead coffins (to block radioactive emissions), by decision of President François Mitterrand, just meters away from her former workshop, which became the Marie Curie Museum.

She is the first woman to enter the Panthéon on her own merits.

Her Children, Her Legacy

Irène Curie was born on September 12th, 1897. A chemist and physicist like her mother, Irène Joliot-Curie, along with her husband Frédéric Joliot-Curie, was awarded the Nobel Prize in Chemistry in 1935 for their discovery of artificial radioactivity as they artificially synthesized new radioactive elements. Both died from diseases attributed to overexposure to radiation.

Eve Curie was born on December 6th, 1904. She wrote a recognized biography of her mother titled *Madame Curie* published in 1938. She married Henry Labouisse, who received the Nobel Peace Prize as the director of UNICEF (United Nations Children's Fund) in 1965.

Marie Curie and her daughters, Irène et Eve, during their trip to the USA in 1921.
(Unknown photographer, public domain)

Her Laboratory Turned Museum

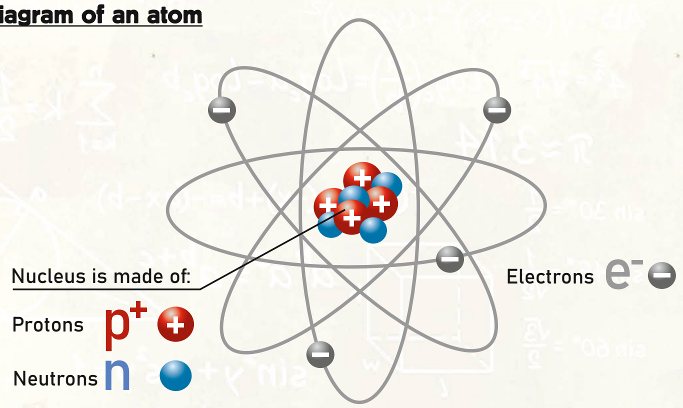
Located at 1 rue Pierre et Marie Curie in the 5th arrondissement of Paris, within the historical premises of the Radium Institute, the Musée Curie showcases the major milestones in the discovery of radioactivity through a rich collection of objects, documents, and archives from the period. Visitors can tour Marie Curie's laboratory and office (which have been reconstructed and decontaminated), which were also used by Irène and Frédéric Joliot-Curie. However, it is not possible to consult Marie Curie's laboratory notebooks, which are still radioactive to this day and are stored at the Bibliothèque Nationale de France with all necessary precautions.

Understanding Radioactivity

What is natural radioactivity?

All matter around us is made up of atoms. These atoms consist of a nucleus around which electrons orbit.

Diagram of an atom



Some of these atoms are described as unstable because their nuclei contain too much energy. To return to a stable state, the nuclei naturally transform into other nuclei. This random, spontaneous, and irreversible transformation (called decay) releases energy in the form of radiation: this is what we call radioactivity.

These naturally radioactive atoms have been present on our Earth since time immemorial: in the atmosphere (carbon 14, radon 222), the earth's crust (uranium 238, uranium 235, radium 226), and our food (potassium 40). Thus, we are surrounded by radioactivity.

Examples of natural radioactive contents:

(Becquerel: the number of decays of radioactive nuclei per second)

- Granite: 1,000 becquerels per kg.
- The human body: a 70-kg individual has an activity of about 8,000 becquerels, with about 5,000 due to potassium 40 (present in muscles).
- Sea water: 10 becquerels per liter.

Radioactivity Explained to Our Children

Radioactivity is a bit like an invisible energy that comes from the tiny parts that make up everything around us, such as rocks, air, and even our bodies. These tiny parts are called atoms. Sometimes, certain atoms are a bit too full of energy and want to calm down. When they do, they change into something else and release a kind of invisible light that we cannot see or feel, but which is very powerful. This invisible light can go through almost everything!

A long time ago, very curious scientists like Marie and Pierre Curie, as well as Henri Becquerel, discovered this invisible phenomenon. They even found new types of atoms that produced a lot of this invisible light. For their discoveries, they received a very important award called the Nobel Prize.

There are two types of radioactivity. The first type comes from nature, from certain atoms found in rocks and everywhere on Earth. The second type is created by humans, in laboratories, to help with many things, like medicine to treat people, or in industry to make things stronger or safer.

Indeed, people have found many usages for this invisible force. For example, it can help to generate electricity, make our food safer to eat by killing germs, and even help doctors look inside our bodies to find and treat diseases. Scientists can also use it to understand the very ancient ages of rocks or fossils.

But, like any powerful thing, it must be handled with great care. Radioactivity can be dangerous if not managed properly. That's why people who work with it wear special protection and follow very strict rules to ensure everyone stays safe.

So, even though we cannot see or feel radioactivity, it has a lot of effects on our world, helping people in many ways, but also requiring a lot of caution to be used properly.

For an anecdote, the banana, a fruit rich in potassium (including radioactive potassium 40), naturally emits radioactivity (130 becquerels per kg). This radioactivity is sufficient to be detected by security portals in the United States. There's no need to stop consuming them, as their natural radioactivity is not harmful to health.

What about artificial radioactivity?

Artificial radioactivity involves creating radioactive atoms that do not exist in nature due to their short lifespan, using a particle accelerator or a nuclear reactor.
The usages of some of these artificially created atoms are numerous (see below). Others, created during the operation of nuclear reactors are nuclear waste that humans have no use for. They must be carefully stored and isolated from any contact with humans.

What are the applications of radioactivity ?

The applications of natural and artificial radioactivity in our everyday lives are numerous. Here is a non-exhaustive list:

Energy, with the production of electricity within a nuclear power plant. The fission of uranium atoms produces heat that transforms water into steam, which powers a turbine connected to an alternator that produces electricity.

Industry, with the production of more resistant and lighter materials by modifying their structure using radiation. For example, by impregnating wood with an irradiated resin, a new material, called densified wood, is obtained. This method, making the wood harder and more resistant to insects and mold, is used, for example, for the flooring of the Grande Galerie of the National Museum of Natural History in Paris.

Construction, where measuring the absorption of radiation allows for measuring the thickness and density of a structure and, for example, finding defects.

In agriculture and the food industry with the irradiation of foods to sanitize them by reducing the number of microorganisms and insects but also to improve shelf life. About 20,000 tons of food products are sterilized each year in France by irradiation, affecting only atoms and molecules, without any risk for health.

In medicine, radioactivity has enabled numerous applications, such as imaging, scanning, brachytherapy and radiotherapy (cancer treatment), and the sterilization of medical equipment. Radioactivity has indeed contributed to improving the diagnostics and screenings of diseases like cancer by introducing radioactive isotopes to produce a medical image through the detection of radiation.

Photo: Brain tomography.

Among the treatments using radioactivity, the technique of brachytherapy involves introducing a strong radioactive source in contact with or inside the cancerous tumor to irradiate and destroy it, without damaging too much the surrounding healthy areas. When this is not possible, doctors resort to external radiotherapy. The source of radiation irradiates the tumor from outside the body.

In science, the carbon-14 dating system (an atom present in all organic matter) allows estimating the age of carbon-based samples (fossil, coal, wood, pigments, organic matter, fabric, etc.) dating from 500 to about 70,000 years and applies to many fields such as archaeology and geology.

How to determine the age of a fossil?

Carbon is a very common element in our environment, notably present in the CO_2 molecule in the atmosphere. This carbon is primarily made up of carbon 12 (stable element) but also a fairly constant small proportion of radioactive carbon 14. This CO_2 is assimilated by living organisms throughout their life through exchanges (breathing, eating, and photosynthesis).

Upon dying, they stop assimilating it. The amount of carbon 14 then decreases over time in a spontaneous, natural, and regular manner due to decay. The amount of carbon 12, however, remains constant. The less carbon 14 remains in the fossil, the older the death. The radioactive period of carbon 14 (the time required for half of the atoms to naturally decay) is known and is about 5,730 years. Thus, measuring the carbon 14 / carbon 12 ratio allows dating the death.

In the arts, it is possible to x-ray dense objects and understand the structure of statues to locate metal inserts and cavities. This information is crucial before moving them to avoid any damage. Radioactivity is also used in the conservation and restoration of works, especially objects made of organic materials (wood, leather, fibers): in 1977, the mummy of Ramses II was saved from larvae and fungi by irradiation.

Radioactive sources are also used to analyze the paintings to trace back to the composition of pigments used by the artist, appraise works, and detect forgeries.

Photo: Ramses II 's mummy exhibited at the Museum of Egyptian Antiquities in Cairo

In the military, with the invention of the nuclear bomb (also called the atomic bomb), using the principle of nuclear fission of uranium 235 and plutonium 239 inducing chain reactions releasing a massive amount of energy and potentially causing huge explosions.

Pierre Curie's speech when receiving the Nobel Prize in 1903 echoed the usage of radioactivity made years later, especially in the design of these atomic weapons: *"One can imagine,* he said, *that in criminal hands radium might become very dangerous, and one might ask oneself whether humanity does benefit from knowing the secrets of nature."*

Timeline Effects

Every player draws one Beaker or round-bottom flask Experiment tile and places it on their personal board.

Each player takes 1 Pitchblende from the supply and places it in their Erlenmeyer flask.

Players who wish may spend 1 Pitchblende to draw a Beaker or round-bottom flask Experiment tile (once per player). The spent cube is returned to the supply.

Players who wish may spend 1 Radium to gain **1 VP** (once per player). The spent cube is returned to the supply.

Players with only one Thesis take 1 Uranium from the supply and place it in their Erlenmeyer flask. Players with two or more Theses take 1 Radium.

Place the 4 available Activity cards from the main board underneath the draw pile and replace them with the next 4 cards from the top of the draw pile.

Each player takes 1 Radium from the supply and places it in their Erlenmeyer flask.

Players who wish may spend 1 Uranium and 1 Radium to gain **1 VP** (once per player). The spent cubes are returned to the supply.

Return all cubes still at the bottom of the tower to the supply.

Players who wish may spend 1 Pitchblende to take a Beaker or round-bottom flask Experiment tile from the draw pile (once per player). The spent cube is returned to the supply.

Players who wish may spend 1 Uranium to take 1 Radium from the supply (once per player). The spent cube is returned to the supply.

Players who wish may spend 2 Radium to gain **1 VP** (once per player). The spent cubes are returned to the supply.

Place the 4 available Activity cards from the main board underneath the draw pile and replace them with the next 4 cards from the top of the draw pile.

Players with exactly one Thesis take 1 Uranium from the supply and place it in their Erlenmeyer flask. Players with exactly two Theses take 1 Radium. Players with three or more Theses gain **1 VP**.

The end of the game is triggered. Players complete the current round up to the last player in the turn order, so that each player has played the same number of turns.