My Great-Great-Aunt Discovered Francium. And It Killed Her.

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Just after Christmas of 1938, a young woman named Marguerite Perey — then 29, with a plain, open face, her eyes intent upon her work — sat at a bench in the Radium Institute of Paris, a brick mansion near the Jardin du Luxembourg. In a glass vessel, she examined fluid containing metal salts. She carefully dosed it with lead and hydrogen sulfide, then with barium, causing the solution to separate into different substances. She was in the final stages of purifying actinium, one of the rarest and most dangerous elements yet discovered, from uranium ore. Ten tons of ore yielded just one or two milligrams of actinium; Perey, who joined the institute as a teenager to be the personal technician for Marie Curie, was an expert in its isolation.

The Curie laboratory hired researchers from across Europe, but Perey was a local girl, the youngest of five children of a flour-mill owner in Villemomble, just east of the city. The death of her father had left the family in financial straits. Her mother gave piano lessons to fill the gap, but Perey had to abandon the idea of going to medical school in favor of a vocational college for chemistry technicians. The Curies often hired the top student from the school as an assistant, and Perey, at 19, was called in for an interview. She later described her first impression of Marie Curie: “Without a sound, someone entered like a shadow. It was a woman dressed entirely in black. She had gray hair, taken up in a bun, and wore thick glasses. She conveyed an impression of extreme frailty and paleness.” A secretary, Perey thought — then realized she was in the presence of Curie herself.

Perey in 1938.

Marie Curie was then a figure of almost religious magnetism in France. She had discovered two elements, polonium and radium, with her husband, Pierre; she had coined the word radioactivity and had won two Nobel Prizes. Curie toured the United States twice, meeting with Presidents Warren G. Harding and Herbert Hoover and receiving donations to equip her lab with radium, which was in demand as researchers experimented with its applications in health care. During World War I, she had personally taken the new medical tool of X-rays onto the battlefields, working from a specially fitted truck with her teenage daughter, Irène, as her assistant. After Perey’s audience with Our Lady of Radium (as a newspaper referred to Curie), she recalled: “I left this dark house, persuaded that it was for the first and last time. Everything had seemed melancholy and somber, and I was relieved to think that I would undoubtedly not return there.”

But she was wrong, and several days later she received a letter telling her that she was hired. For a decade, Perey’s day-to-day duties consisted largely of a curious ritual: sifting out pure actinium from all the other components of uranium ore so Curie could study its decay. Perey steeped samples in ammonia, applied acids to them and mixed them with ingredients that would cling only to the substances she wanted. At each step, unwanted elements and contaminants were burned, leached, evaporated or poured away, leaving behind a purer and purer substance. After Curie's death in 1934, the lab continued its study of actinium under the supervision of Andre Debierne, its discoverer, and Irène Joliot-Curie, Curie's daughter. It was not until a few years later, however, that Perey first noticed something odd about the actinium she purified, as Jean-Pierre Adloff, a physicist who later worked with her, has recounted. It was emitting unexpected radiation. She worked on it until midnight and eventually pleaded with Debierne for a three-week leave from her normal duties to figure out where the radiation was coming from.

By adding cesium chloride, Perey coaxed the actinium to form crystals; then, through a series of meticulous tests, she laid down the proof that this radiation was something new. Like her mentor, she had discovered an element, which she named francium, in honor of her country. But the story of Marguerite Perey — which I have known in some detail since childhood, because she was my great-great-aunt — ends very differently.

There is a common narrative in science of the tragic genius who suffers for a great reward, and the tale of Curie, who died from exposure to radiation as a result of her pioneering work, is one of the most famous. There is a sense of grandeur in the idea that paying heavily is a means of advancing knowledge. But in truth, you can't control what it is that you find — whether you've sacrificed your health for it, or simply years of your time.

Sixty years before Marguerite Perey began her work at the Radium Institute, Dmitri Mendeleev, a Russian chemist, published his "tentative system of the elements." Mendeleev's diagram mapped the substances that could not be broken down into others, the fundamental components of matter. It wasn't the first time a scientist tried to diagram the elements, but his was the most direct predecessor of the periodic table we use today. When he arranged known elements in a grid by weight, they fell into groups that had similar qualities. Scrutinizing the holes in his diagram, where slots remained for elements not yet discovered, Mendeleev was able to predict what those elements would be like. Below cesium, for instance, he suggested a hypothetical element he dubbed eka-cesium; it was the spot that francium would eventually fill.

Mendeleev predicted that eka-cesium would share some of the properties of its family — the alkali metals. The uses of alkali metals had already begun to be realized. Lithium, discovered in 1817, went on to grease plane engines, build the batteries that today fuel electric cars and become one of the most powerful mood-stabilizing drugs. The identification of sodium and potassium would feed into the science of nutrition. Cesium atoms are at the core of atomic clocks so accurate that had they been set at the time of the dinosaurs, they would be less than a second off today. Though many of the applications came some years after the discoveries, the power of uncovering new forms of matter was clear.

As researchers developed new ways to identify elements over the course of the 19th century, cry after cry sounded in the scientific literature — Gallium! Scandium! Holmium! Thulium! Praseodymium! Scientists soon discovered several elements that Mendeleev predicted. Three decades after Mendeleev published his diagram, a cry came from Pierre and Marie Curie: Polonium! A mere five months later, in December 1898, another call came from the Paris lab: Radium! It was one of a half-dozen elements discovered that year alone.

In this parade of new elements, some gave off radiation, rays of particles released by atoms as they decayed into other elements, known as their daughters. To understand how radioactivity works, think about the structure of an atom. At its core, or nucleus, it has a cluster of particles called protons and neutrons, and around them swirl a cloud of electrons. An atom of uranium 235, for instance, has 92 protons, 92 electrons, and 143 neutrons. But this arrangement is unstable. Soon the uranium will start to shed particles. It might shed two protons and two neutrons, a process called alpha decay, converting it to thorium, element 90. If thorium then turns a proton into a neutron and sheds an electron, called beta-minus decay, it becomes protactinium, element 91. This series of transformations from one element to another is called a decay chain. As the atom progresses down the decay chain, some routes are favored above others. Polonium 215 decays into lead almost all of the time, taking the alpha-decay route. Only a minuscule fraction of Polonium 215 takes the beta-decay route, to become astatine. The time it takes for half a sample of an element to decay, its half-life, can range from fractions of seconds to billions of years.

How quickly an element decayed and how it did so — meaning which of its component parts it shed — became the focus of researchers in radioactivity. Apart from purely scientific insights, there was a hope that radiation could lead to something marvelous. X-rays, a kind of radiation discovered by Wilhelm Roentgen and produced by accelerated electrons, had already been hailed as a major medical breakthrough and, in addition to showing doctors their patients' insides, were being investigated as a treatment for skin lesions from tuberculosis and lupus. In her 1904 book "Investigations on Radioactive Substances," Marie Curie wrote that radium had promise, too — diseased skin exposed to it later regrew in a healthy state. Radium's curious ability to destroy tissue was being turned against cancer, with doctors sewing capsules of radium into the surgical wounds of cancer patients (including Henrietta Lacks, whose cells are used today in research). This enthusiasm for radioactivity was not confined to the doctor's office. The element was in face creams, tonics, even candy. According to the Encyclopaedia Britannica article that Curie and her daughter wrote on radium in 1926, preliminary experiments suggested that radium could even improve the quality of soil.

Perey (left) and Cotelle in the garden at the Radium Institute in 1930.

And yet from the beginning, there were signs that radiation had sinister powers. In 1901, Henri Becquerel, the first person to observe radioactivity, reported strange burns he received from the vial of radium he carried in his waistcoat pocket. The burns appeared on the Curies' hands as well. People who worked with X-rays at the beginning of the 20th century had a known tendency to lose their hair and develop burns on their skin and even cancer. In 1904, Clarence Dally, who was Thomas Edison's X-ray assistant, died of cancer after having both his arms amputated to try to keep it from spreading. For all its anticipated promise in battling cancer, radiation was also clearly carcinogenic.

Perhaps the most tragic demonstration of this involved workers at the United States Radium Corporation factory in Orange, N.J., which in 1917 began hiring young women to paint watch faces with glow-in-the-dark radium paint. The workers were told that the paint was harmless and were encouraged to lick the paintbrushes to make them pointy enough to inscribe small numbers. In the years that followed, the women began to suffer ghoulish physical deterioration. Their jaws melted and ballooned into masses of tumors larger than fists, and cancers riddled their bodies. They developed anemia and necrosis. The sensational court case started — and won — by the dying Radium Girls, as they were called, is a landmark in the history of occupational health. It was settled in June 1928, four months before Marguerite Perey arrived at the Radium Institute to begin a 30-year career of heavy exposure to radiation.

Through all that, little seems to have changed at the institute, where a long tradition of lax safety practices continued. Two former Radium Institute chemists died in quick succession from brief, violent illnesses ("A New Victim of Science," read a 1925 newspaper announcement of the second death). In 1927, Sonia Cotelle, a Radium Institute chemist who worked with polonium, began losing her hair rapidly. Cotelle later died from radiation exposure. Although radiation's connection to cancer was known and the lab's own employees had clearly suffered, the Curies made few adjustments to protocol. Marie Curie's principal adaptations were to ask scientists to submit to blood tests and to encourage workers to take short breaks in the garden, which provided no real protection. When a journalist asked about the watch painters in New Jersey, she suggested that they eat calf's liver to combat anemia. The great work went on.

In her years of working for the Curies, Marguerite Perey had not had an education beyond her technician's training, but after her discovery of francium, she was given a grant to study for her graduate degree. In 1946, she defended her Ph.D. thesis at the Sorbonne. Her brother Jacques and his son, Bernard, then 15, were at her defense. Bernard, now 84 and living in Halifax, Nova Scotia, told me about it this fall. They entered the hall through Place Paul-Painlevé, named after a mathematician who became prime minister of France. "Some very wise-looking men asked her questions," Bernard said wryly. He recalls that she answered every one correctly.

In general, awe suffuses the family folklore on Perey. While we were talking on the phone, Bernard's wife, Colette, chimed in to say that the first person in the family Bernard told her about was Marguerite. "He showed me a picture of her and also showed me the table, and francium, the one she discovered," she said. Bernard's granddaughter recently had a moment of reflected glory in her elementary-school class, he related, when the teacher, who had just learned of the girl's connection, told the children, "We have someone famous with us today," and went on to teach a lesson on the periodic table.

When I was in sixth grade, I did a report on francium myself. I was proud of Marguerite in that vague way you might be of prominent relatives, though they may be distant or long dead. The shape of a scientific life was familiar to me then: My grandfather Francis is a nuclear physicist who worked at the Oak Ridge National Laboratory, built as a secret Manhattan Project facility. My grandmother was also a nuclear physicist at the lab, my mother is a futurist, my father is an ecologist and my sisters are, today, an engineer and a neuroscientist. To uncover the nature of the physical world and learn its ways is of unquestionable value to us. When Marguerite's name came up occasionally, we all seemed to experience the quiet thrill of gratification that, in our clan of professional truth-seekers, one of us had achieved some measure of scientific immortality. But as I grew older, her legend took on a slightly different shape.

Perey, like Curie, had great ambitions for her discovery. In 1949, she was made the head of the department of nuclear chemistry at the University of Strasbourg, where she began to explore the biological effects of the element. "It is my great hope that francium will be useful for the establishment of an early diagnosis of cancer," Perey wrote. "My unconditional wish would be to accomplish this task someday." She published experiments showing that it gathered in tumors more quickly than in healthy tissue. But before long, she grew sick.

We know now that alpha and beta particles emitted in radiation attack DNA and that the mutations they cause can lead to cancer. Ingested radioactive elements can concentrate in the bones, where they continue their decay, in effect poisoning someone for as long as that person lives. By the time Perey made her discovery, she was already heavily contaminated. She spent the last 15 years of her life in treatment for a gruesome bone cancer that spread throughout her body, claiming her eyesight, pieces of her hand and most of the years in which she had planned to study francium. As the disease progressed, she warned her students of the horrible consequences of radiation exposure. Francis, my grandfather, says he recalls hearing that when she walked into labs with radiation counters in her later years, they would go off.

In biographies of Marie Curie, the dangerous anemia she contracted from her work sometimes sounds romantic, like the illness of a tubercular poet. (Indeed, her journey to the sanitarium in the Alps where she died was undertaken because doctors thought she had tuberculosis.) But Geoff Rayner-Canham, co-author of a book on early female radiochemists, "A Devotion to Their Science," feels that there was something somewhat grotesque about the Curies' behavior, especially concerning the safety of those who worked in their lab. Speaking of Perey and her compatriots, who followed the Curies' lead, Rayner-Canham says, "They literally did sacrifice their lives on the altar of radioactivity."

The more you read about how research progressed in the Radium Institute, the less romantic the story seems. Several potent accounts come from Elizabeth Rona, a chemist who worked in various European radioactivity labs. She wrote of a lab assistant, Catherine Chamie, who transported radioactive sources to and from a safe each day on a cart, shielded poorly by lead bricks; Chamie later died from exposure. One day, Curie let Rona watch as she casually burned off radon emitted by a flask of radium. The gas exploded, shattering the flask; neither wore protective gear. Rona records a litany of radioactivity researchers who followed Chamie, their lungs, hands and bones falling apart. The thumbs, forefingers and ring fingers of their left hands were especially prone to damage, because of the way they were exposed to the radioactive substances they poured from flask to flask without gloves.

Researchers in the Curie laboratory's library in 1930. Seated, from left: Perey, L. Razet, Isabelle Archinard and Cotelle. Standing, from left: André Régnier, Alexis Yakimach, R. Grégoire, R. Galabert, T. Tcheng and Frédéric Joliot-Curie.

Bryce DeWitt, the husband and colleague of Cecile DeWitt-Morette, a physicist who worked in the lab in the 1940s, related that Irène Joliot-Curie "had a penchant for asserting that anyone who worried about radiation hazards was not a dedicated scientist." There are photographs of Joliot-Curie sucking a fluid up a glass tube to move it from one container to another, a practice called mouth pipetting. The historian Anne Fellinger has asserted that the substance is polonium — known to most people today as the radioactive poison used to murder the former Russian spy Alexander Litvinenko in 2006.

Over the years, historians have pondered what drove the Curies to throw caution so thoroughly to the wind. Perhaps it was inconceivable to them that the benefits of their research would not outweigh the risks to themselves and their employees. In a field in which groundbreaking discoveries were being made and the competition might arrive there first, speed was put above other concerns, Rona noted. But you almost get the impression that in the Curie lab, dedication to science was demonstrated by a willingness to poison yourself — as if what made a person's research meaningful were the sacrifices made in the effort to learn something new.

It turns out that at any given moment, there is far less than a gram of francium on earth: only a tiny fraction of actinium decays in a way that produces francium, and after a few fleeting minutes, it winks out of existence again. Perey, for all her suffering, discovered an element that almost doesn't exist.

Her sacrifice filled a hole in the periodic table, but it did not change cancer medicine, as she had hoped. And after francium, elements were no longer discovered first in nature but were increasingly made artificially. They became curiosities — though still significant to physicists — rather than insights that changed the world. Science moved on, as it does;

in 20 years' time, much of the work that makes headlines now — neuroscience, string theory — may have a totally different meaning from what it does today.

In general, scientists whose risks pay off in the ways they expect are the ones who become the most famous, who get their stories written in romantic and memorable terms. This is particularly true if those expectations are grandiose and the risks they take are tragic. But such people represent a vanishingly small part of those who dedicate their lives to science. "We have this selection bias on when it does work out in an extraordinary way," Lynette Shaw, a sociologist who studies how we assign value to ideas, objects and people, told me. Perey's story "gets to this deep question about what's the value in doing things? Is it the end result? Or is it just because it has inherent worth to pursue them?"

We should celebrate scientists not solely for their accomplishments but also for their courage and the tenacity required to discover anything at all. There are brave people out there working right now. They are brave not because they are killing themselves slowly or leaping from airplanes or catching rare tropical diseases, although scientists have done all those things. They are brave because of the intense emotional risks of trying to do something no one has done before by following your own lead. Radiation is a potent allegory for human life. Everything is always, inevitably falling apart; we are all in arrested decay. Our greatest achievements may become at best footnotes; few people remember us; we can't know what will eventually come of our work.

Luis Orozco is a professor of physics with the Joint Quantum Institute at the University of Maryland, where he studies the forces that hold together nuclei. He is 56 and comes from Guadalajara, Mexico, has an easy laugh and enjoys explaining the finer points of atomic structure. He and his collaborators are among the few people today who conduct research on francium.

"We make it these days in an accelerator," Orozco says. They bombard uranium carbide with protons, and it separates into a variety of elements, one of which happens to be francium. The amounts are tiny, and after a few short minutes they are gone. But it's enough time to perform some very specialized experiments, which are the focus of Orozco's research.

Orozco and his colleagues make francium because they think it is a perfect candidate to help understand the force behind beta decay. It has a heavy nucleus, which means there are many opportunities for particles to interact. It can be easily trapped, which is not true of other elements they might use. And it also emits and absorbs light at similar frequencies, which is useful for the experimenters. Someday, Orozco hopes, as the years pass and data are added to the compendium of human knowledge, francium will help researchers better understand the structure of matter.

But it won't help cure cancer. When I bring up Marguerite Perey's ambitions for her discovery, Orozco replies: "Oh! No." He sounds surprised at the idea.