



# The Los Alamos connection to Maria Goeppert Mayer's Nobel legacy

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By Heather Hershey, digitizer-archivist, National Security Research Center

From an early age it was expected that Maria Goeppert Mayer would continue the Goeppert family tradition of professorship.

Her father was a sixth-generation professor and she was to be the seventh. To him, his daughter's gender was irrelevant, but rules at universities regarding the wife of a fellow academic complicated the Goeppert family's succession plan.

Universities' nepotism regulations, meant to discourage supervisors from hiring relatives, denied employment to wives of professors and would haunt Goeppert Mayer throughout her career.

For many years, each time her husband was offered a professorship, Goeppert Mayer was denied a similar position at the same university despite her formidable qualifications. Instead, she held volunteer positions, allowing the universities to benefit from her incredible scientific abilities, without having to pay her a salary.

Throughout her career, much of which was work in unpaid positions and that she said was "just for the fun of doing physics," Goeppert Mayer made contributions to the fields of nuclear physics, physical chemistry, and mathematics.

Some of her earliest work in her doctoral research presented the theory of two-photon absorption (2PA), which, after the invention of lasers in 1960, was experimentally confirmed. To honor Goeppert Mayer, the unit for 2PA cross-sections is called a Goeppert Mayer (GM) unit.

Near the end of her career, in 1963, she shared one-half of the Nobel Prize in Physics for her work on the nuclear shell model, which is the basis for understanding nuclear structure. Goeppert Mayer was just the second woman to be awarded the prize in physics (it would be another 55 years before the third).

In between these feats, Goeppert Mayer contributed to the Manhattan Project's efforts to create a nuclear weapon to help end World War II, simultaneously helping usher the world into the Atomic Age.

## The early years: 1906-1943

Goeppert Mayer was born on June 28, 1906 in Kattowitz, Germany (now Katowice, Poland), the only child of Friedrich Goeppert and Maria Wolff. In 1910, Friedrich

became a professor of pediatrics at Göttingen University, and moved the family from Kattowitz to Göttingen.

Goeppert Mayer attended public and private schools and entered Göttingen University in the fall of 1924. She began her studies in mathematics. At the request of Max Born, a family friend and professor of theoretical physics, she joined his quantum mechanics seminar. It was during this seminar that she discovered she preferred theoretical physics to mathematics, so she changed her course of study and became Born's doctoral student.

In 1928, Goeppert Mayer met Joseph Mayer, an American chemist on fellowship at Göttingen University. Joe arrived at the home Goeppert Mayer shared with her mother to inquire about renting a room. Because of the financial strain caused by Friedrich Goeppert's sudden death the year before, the family was renting rooms to students.

Joe and Maria were married January 18, 1930. In March, Goeppert Mayer received her doctorate, and soon after Joe accepted a position in the chemistry department at Johns Hopkins University. The couple left Germany for Baltimore.

Because of the nepotism regulations, Goeppert Mayer was not offered a paid position at the university. Instead, she was a volunteer associate in the physics department until 1939, when the couple moved to Columbia University in New York. Nepotism rules would again keep Goeppert Mayer from a paid position there. At the request of Harold Urey, professor of chemistry, she was a volunteer lecturer in the chemistry department.

In 1941, Goeppert Mayer was offered her first paid job: a substitute position at Sarah Lawrence College. She taught mathematics that first year, and in June 1942 she was reappointed to the science faculty. During the 1942/1943 academic year, Goeppert Mayer taught four courses: two in mathematics, one in physics, and one in physical chemistry. She was also still a volunteer chemistry lecturer at Columbia University.

## **Los Alamos involvement: 1944-1945**

In September 1943, Urey, now the director of the Substitute Alloy Materials (SAM) Laboratories at Columbia, needed an expert in spectral analysis to lead a team researching the photochemical method for uranium isotope separation. Urey was familiar with Goeppert Mayer's earlier work and knew she was the right person for the job. He wrote to the president of Sarah Lawrence College, requesting a one-year leave of absence for Goeppert Mayer to return to Columbia full time for "an important war project."

The SAM Laboratories were conducting research for the Manhattan Project, which was the U.S.-led effort to create the world's first atomic weapons. The focus of the wartime research at Columbia was looking into the uranium isotope separation processes required to produce the weapons-grade uranium desperately needed by the scientists at the clandestine laboratory in Los Alamos.

Urey's request was granted, and Goeppert Mayer returned to Columbia full time. Goeppert Mayer supervised a team at the SAM Laboratories that was researching the photochemical method for uranium isotope separation. This work involved analyzing the spectra of uranium-235 and uranium-238. Within a few months, the photochemical method was deemed impractical and was abandoned. Goeppert Mayer was moved to the team researching gaseous diffusion. Gaseous diffusion and electromagnetic

separation were deemed more practical, given the time constraints of producing a weapon before the Nazis had their own.

Meanwhile, in late May of 1944, Los Alamos Laboratory Director J. Robert Oppenheimer and physicist Edward Teller needed a group that could undertake opacity calculations, which dealt with the properties of radiation at high temperatures. Oppenheimer asked Gen. Leslie Groves, who was leading the Manhattan Project and overseeing the secret work in Los Alamos, to allow the work to take place at the SAM Laboratories at Columbia. When it came to deciding who should lead the Opacity Project, Goeppert Mayer was an obvious choice. She was already involved with the Manhattan Project efforts and was a skilled mathematician and theorist, head of a team of researchers, and an expert in spectral analysis.

With Groves' approval, Goeppert Mayer was hired as a consultant for Los Alamos. Teller would oversee the project from Los Alamos, as his frequent travels to New York for other Manhattan Project business would allow him to meet with Goeppert Mayer at Columbia without raising suspicions.

At the SAM Laboratories, Goeppert Mayer enlisted the help of two of her graduate students.

The three began work on the opacity calculations and were in regular communication with Teller. On May 21, 1945, Goeppert Mayer arrived in Los Alamos to continue the opacity calculations with Teller. While not directly beneficial to the development of the fission weapons at Los Alamos during the war, the calculations were later applied to the development of the hydrogen bomb.

## **Nobel Prize, professorship, death: 1946-1972**

In 1946, Goeppert Mayer and her husband moved to Chicago. Joe was appointed professor in the chemistry department at the Institute for Nuclear Studies at the University of Chicago. Despite her work for the Manhattan Project, Goeppert Mayer was once again denied a paid position and worked for free as a professor of physics at the institute.

In July, Goeppert Mayer was offered the position of senior physicist at the newly formed Argonne National Laboratory in Chicago. She continued her unpaid professorship at the University of Chicago, while working part time at Argonne. It was during her time at Argonne that Goeppert Mayer would develop the nuclear shell model that would later earn her the Nobel Prize in Physics.

Goeppert Mayer was working on a project with Teller to determine the origin of elements. They were looking at isotope abundances when Goeppert Mayer observed patterns. She noticed that nuclei with 2, 8, 20, 28, 50, 82, or 126 protons or neutrons were stable (known as the magic numbers). Goeppert Mayer recognized the importance of these numbers and speculated they could help describe the structure of the nucleus, and perhaps nuclei had a shell structure similar to the electron shell structure in atoms. Goeppert Mayer was not the first to notice this phenomenon, which was studied in the 1930s, so she reviewed the earlier research and continued to study the data.

By 1948, she had the data, but not the theoretical explanation for the shell structure of nuclei. She presented her data in a paper "On Closed Shells in Nuclei," published in the *Physical Review* journal that same year. Early the next year, during one of many discussions of shell structure with physicist Enrico Fermi, he remarked, "Is there any

indication of spin-orbit coupling?” This was the breakthrough Goeppert Mayer needed. She now had her theoretical explanation for shell structure, and the spin-orbit-coupling shell model of nuclei was presented in the February 4, 1949 issue of the Physical Review. Around this same time J. Hans D. Jensen, a German physicist, came to the same conclusions as Goeppert Mayer. The two met in 1951 and started a collaboration that culminated in 1955 with the publication of their book, Elementary Theory of Nuclear Shell Structure.

In 1960, Goeppert Mayer accepted a full professorship in physics at the University of California at San Diego. It was a paid position. Soon after arriving in San Diego, Maria had a stroke at the age of 53, which would affect her health for the remainder of her life. However, she continued to teach and contribute to the field of physics.

In 1963, Goeppert Mayer was awarded half of the Nobel Prize in Physics, sharing it with Jensen for their discoveries concerning nuclear shell structure. The other half of the prize that year was awarded to Eugene Paul Wigner for unrelated work.

Goeppert Mayer died on February 20, 1972, after suffering from a massive heart attack and then spending weeks in a coma. She was survived by her husband, daughter, and son.

According to the Scientific American, before her death Goeppert Mayer told a group of high school girls, “Become fully educated women and promote the understanding of science in any way you can. Our country needs your help. My generation has played its part. It is up to you to carry on.”

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**(505) 667-7000**

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