# Stafford Leak Warren (1896–1981) [1]

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Stafford Leak Warren studied nuclear medicine in the United States during the twentieth century. He used radiation [3] to make images of the body for diagnosis or treatment and developed the mammogram, a breast imaging technique that uses low-energy X-rays to produce an image of breasts. Mammograms allow doctors to diagnose breast cancer in its early and most treatable stages. Warren was also a medical advisor to the Manhattan Project, the US government's program to develop an atomic bomb during World War II, and he was responsible for the health and safety aspects of the Trinity Test, the first atomic bomb test in the US. Warren's invention of the mammogram has allowed physicians to diagnose breast cancer in women during its most treatable stages, preventing deaths due to breast cancer.

Warren was in born in Maxwell, New Mexico, on 19 June 1896. In 1914, he enrolled at the University of California, Berkeley, in Berkeley, California, for his undergraduate studies. He graduated in 1918 with a bachelor of arts degree. After his undergraduate education, Warren attended the medical school at the University of California, San Francisco in San Francisco, California. On 22 May 1920, Warren married Viola Lockhart, with whom he had two sons and a daughter. In 1922, Warren graduated from medical school and completed his postdoctoral work at Johns Hopkins School of Medicine in Baltimore, Maryland, and at Harvard University [4] in Cambridge, Massachusetts.

Warren began his career in radiology at the University of Rochester School of Medicine in Rochester, New York. Radiology is a medical specialty that uses imaging like X-rays to diagnose or treat diseases. At the time, X-rays were commonly used to produce images of bones. In 1926, Warren became assistant professor of medicine in the Department of Radiology at the University of Rochester School of Medicine. Warren was a part of the founding faculty of the Rochester medical school, which opened in 1925. While serving as an assistant professor, Warren studied radiography, an imaging technique that uses electromagnetic radiation [3] such as X-rays to view internal structures of non-transparent objects, like tumors. Specifically, Warren studied the effects of radiation [3] on dogs and their bone marrow because radiation [3] was a new technology and all of its effects were not known. Along with radiography, Warren studied the effects of artificial fever, or inducing heat in the body, and its application to treating gonorrhea, a sexually transmitted infection.

During his time at the University of Rochester, Warren developed mammography using X-rays. When a physician X-rays tissue, like breast tissue, the speed at which the rays get through the tissue reveals the density of that tissue. In breasts, denser tissue can indicate that that tissue is cancerous. Warren used X-rays to diagnose breast cancer. However, Warren was not the first to study breast tissue using X-rays. In 1913, scientist Salomon Albert studied cancerous breast tissue removed during surgery using X-rays at the Humboldt University of Berlin [5] in Berlin, Germany. Salomon detected different forms and stages of breast cancer by analyzing over 3,000 cancerous tissue specimens using X-rays. However, Salomon never applied X-ray imaging to the practice of diagnosing breast cancer in presumably healthy women. Warren, who was studying the effects of radiography on dogs, transitioned to studying applications of X-ray on female breasts. He developed the mammogram, essentially an X-ray image of breast tissue. Physicians use mammography to image breasts for breast cancer detection. A mammogram is the image produced through mammography, which doctors look at to diagnose breast cancer.

In 1930, Warren adopted general X-ray equipment to diagnose breast cancer and published a paper on the use of X-rays to study breast tissue. In his paper, he described using X-rays to track changes in patients' breast tissue brought about by pregnancy [6] and infection. By tracking those changes, Warren mapped the density of breast tissue and recorded how tissue density changed due to certain conditions. To view the patient's breasts for diagnosis of breast cancer, Warren developed a stereoscopic method, meaning he compiled two images taken from different angles to be viewed together. The stereoscopically produced image, called the mammogram, more clearly revealed different densities and depths in the X-ray images. He demonstrated the mammogram's effectiveness and accuracy for diagnosing breast cancer by imaging 119 women. He correctly diagnosed breast cancer with mammograms in fifty-four out of the fifty-eight patients with breast cancer. Warren's mammogram made the diagnosis of breast cancer possible without biopsy, a surgical procedure that extracts sample tissue to test for cancer. As of 2017, physicians commonly use mammography to diagnose breast cancer.

Warren continued to teach at the University of Rochester until 1943, when he was appointed colonel in the US Army Medical Corps and chief of the Manhattan Project's medical section. The Manhattan Project was a secret US military project started in 1942 to produce the first US nuclear weapon for use in World War II. Leslie R. Groves, the director of the Manhattan Project, asked Warren to study radiation [3] to identify possible health and safety issues. Warren collaborated on the task with Hymer L. Friedell, who worked at the Manhattan Project's headquarters in New York City, New York. Friedell also had a background in radiology, and he had studied with radiologist Robert Stone at the University of California, Berkeley.

To serve as consultant on the Manhattan Project, Warren first relocated to New York City, New York, before moving to Oak

Ridge, Tennessee, the headquarters of the project. His initial duties involved staffing hospitals in Oak Ridge, Tennessee, in Richland, Washington, and in Los Alamos, New Mexico, for medical research on the effects of radiation [3]. Warren also commanded health and safety programs for the Manhattan Project that involved protecting workers who handled toxic chemicals, high-pressured gas, high voltages, explosives, radiation [3], and fissile materials. Warren's work on safety measures and health precautions led to large improvements in injury and death rates on Manhattan Project work sites. Between January 1943 and June 1945, sixty-two Manhattan Project workers were killed and 3,879 workers were disabled. However, those death and injury rates were sixty-two percent below the death and injury rates for private industries working with nuclear radiation [3]. In 1945, the National Safety Council in Washington, D.C., awarded the Manhattan Project the Award of Honor for Distinguished Service to Safety, in part due to Warren's work to increase safety measures and health precautions.

During the 1940s, Warren also participated in the first atomic bomb test and assessed the radiation [3] damage caused by subsequent atomic bombs. On 6 July 1945, Warren directed the medical and safety sections for the Trinity nuclear test, the first detonation of an atomic bomb, in Alamogordo, New Mexico. Warren set up a network of geiger counters, devices that detect radiation [3], to watch for nuclear fallout that would endanger the workers' health. No problems arose during the Trinity test. On 6 and 9 August 1945, the US military dropped atomic bombs on Hiroshima, Japan, and Nagasaki, Japan. A month later, Warren and a survey team arrived in Hiroshima with portable geiger counters to assess the radiation [3] damage and medical response of the Japanese. Warren found that radiation [3] from the bomb had caused disastrous health effects and that large quantities of radiation [3] pollution remained in the soil.

While the US and the Soviet Union were racing to make nuclear weapons in the 1940s, Warren directed the radiological safety section for a series of nuclear tests under Operation Crossroads. Operation Crossroads was a US military operation that tested nuclear bombs on Bikini Atoll, Marshall Islands. Warren assessed radiation [3] contamination on the island and implemented methods to limit the amount of radiation [3] fallout. Warren noted the appalling effects of radiation [3] observed in Bikini Atoll in the article "Conclusions: Tests Proved Irresistible Spread of Radioactivity." In the article, Warren describes the debilitating effects of radiation [3] on the human body, such as radiation [3] sickness and cancer. On 6 November 1945, Warren left the Army to serve as Chief of the Medical Section of the Atomic Energy Commission, the civilian agency that replaced the Manhattan Project in developing nuclear weapons.

In 1947, Warren left the Atomic Energy Commission to become the first dean of the David Geffen Medical School at the University of California, Los Angeles in Los Angeles, California. He appointed professors Charles Carpenter, Andrew H. Dowdy, and John S. Lawrence, his former colleagues from the University of Rochester. He also appointed William P. Longmire Jr., a plastic surgeon from Johns Hopkins University [7] in Baltimore, Maryland. The five researchers became the founding faculty of the new medical school, which opened in 1955. From 1955 to 1962, Warren worked as dean of the David Geffen Medical School.

In 1962, Warren stepped down as dean and became Vice Chancellor of Health Service at the University of California, Los Angeles, managing the Health Service department for the university. That same year, John F. Kennedy, the president of the US, formed a twenty-six-member panel of physicians and scientists, including Warren, for advice regarding mental disabilities. The succeeding US president, Lyndon B. Johnson, continued meeting with the panel throughout his presidency. In 1962, the panel wrote a report, which prompted Public Law 88-164 of 1963. That law authorized the funding of developmental research centers in university affiliated facilities and community facilities for people with mental disabilities.

In 1963, Warren's wife Viola died. Two years later, in 1965, Warren returned to the University of California, Los Angeles, as professor emeritus. In 1970 Warren married to Gertrude Turner Huberty. A year later, the US Department of Energy in Washington D.C. awarded Warren the Enrico Fermi Award for his contributions to science and medicine. The US Army also awarded Warren the Army Distinguished Service Medal and Legion of Merit awards. Warren died on 26 July 1981 in Pacific Palisade, California.

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