CONTRIBUTIONS FROM WOMEN TO THE RADIATION SCIENCES: A BRIEF HISTORY

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Abstract—**Contributions from men to radiation science are well known, particularly the early contributions from such luminaries as William Roentgen, James Chadwick, Niels Bohr, Robert Oppenheimer, and the like. Although not ignored per se, beyond Marie Curie and Lise Meitner, the contributions of female nuclear scientists are not as widely recognized. This paper provides a concise historical summary of contributions to radiation science from the discovery of radiation through the current status of international leadership within the radiation protection community. Beyond lead scientists and academics, this paper also considers support personnel as well as the role women have played in the advancement of radiation epidemiology.**
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Key words: historical profiles; epidemiology; Health Physics Society; radiation protection

INTRODUCTION

THIS PAPER presents a synopsis of the contributions women have made related to the broad field of nuclear and radiation science. Studies have shown that having a role model to identify with is an important factor in the recruitment and retention of women (or other minorities) in the sciences, where women are still an underrepresented group (Dimitriadi 2013; Young et al. 2013). Recognizing the historical contributions from women, then, is important not just for the history of science but for communicating the value of and continued need for women in science. Beyond providing stories of inspiration, considering this history of accomplishment (and in many cases sacrifice) provides insight into how and why things have changed as well as the potential for identifying legacies of past events in current situations (Dimitriadi 2013).

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This work highlights only a sampling of female scientists, engineers, and mathematicians who have contributed to the current state of knowledge and technology and is not meant to be a comprehensive history of women in the field. It draws from many excellent biographies and biographical essays that the interested reader is referred to for more in-depth discussions and analysis (see works cited).

THE WOMEN

The early years: 1895–1930

Since the discovery of ionizing radiation in 1895, women have made numerous contributions to the field of radiation science. Many of these women faced significant personal and professional challenges, particularly those living in the early to mid-twentieth century who provided the foundation of nuclear science. Early female scientists, and women in general, encountered many barriers in pursuit of their occupational field of choice due to their gender. Even exceptionally talented and qualified women had very limited educational opportunities, particularly in higher education. Also, even after receiving an advanced degree, most women had to take unpaid positions (Byers and Williams 2006). For perspective, at the time of Roentgen's discovery of x rays in 1895, New Zealand (a British colony at the time) was the only country in which women had the right to vote (Ramirez et al. 1997). Only two more countries (Australia and Finland) granted women the right to vote by the time Marie Curie, a Polish-born French physicist and chemist, won her second Nobel Prize in 1911. Between 1915 and 1920, 13 more countries granted this right, with 20 more between 1920 and 1945 (Ramirez et al. 1997). As France granted women's suffrage in 1944, Curie (1867–1923) was never allowed to vote in her lifetime, despite the fact that she was, and still remains, the only person to be a Nobel laureate in two scientific disciplines (Greer and Tolmachova 2011).

Marie Curie (née Sklodowska) shared her first prize, the 1903 Nobel Prize in Physics, with her husband Pierre for their combined research on radiation and radioactivity, along with Henri Becquerel, who was awarded one-half of the prize for the initial discovery of radioactivity. As an aside, "radioactivity" was a term first used by Curie in

1898. This was the same year she became the first woman in France to receive a doctorate. Five years later, Curie became the first female professor at the Sorbonne in Paris, having taken her husband's place after his untimely death in 1906. Soon after, she was independently awarded the 1911 Nobel Prize in Chemistry for the 1898 discovery of polonium as well as the discovery and isolation of radium (Sime 1996; Greer and Tolmachova 2011; Wirten 2015).

Although Curie is the most recognizable female radiation scientist, and arguably one of the most famous historical figures in science in general, there were other women who made related discoveries. For example, Harriet Brooks (1876–1933), a Canadian nuclear physicist and a student of Ernest Rutherford, discovered radon in 1901 and in 1904 became the first person to observe nuclear recoil following radioactive decay (Rayner-Canham and Rayner-Canham 1992). She worked as a tutor at a women's college for 2 y after that, at which time she became engaged and was promptly asked by the dean to resign her position. Brooks found this ultimatum highly inappropriate, and the stress of the situation led her to leave both the position and the engagement. She worked briefly in Curie's lab but ironically ended up forming a second engagement and leaving research, seemingly for the social and financial stability marriage provided (Rayner-Canham and Rayner-Canham 1992; Byers and Williams 2006).

With a similar view on the supposed incompatibility of marriage and science (for women, at least), Lise Meitner (1878–1968), an Austrian-born German physicist, never married and devoted her life's work to nuclear physics; she was of the mindset that science required one's complete dedication (Sime 2005). Meitner discovered protactinium in 1917 in collaboration with the radiochemist Otto Hahn, who was also her close friend. That same year, Meitner became head of the physics section at the Kaiser Wilhelm Institute for Chemistry (KWI) and then a professor in 1919. No other women were given permanent scientific positions at this institution during her tenure there, and only three are listed as authors on the institution's publication list. Meitner herself never published with another woman nor graduated a female doctoral student (Sime 2005). A few years later (1922), Meitner offered one of the first explanations (albeit not quite right) for the Auger effect, named for the French scientist Pierre Auger, who experimentally observed said effect in 1923 and offered its complete theoretical explanation (Duparc 2009).

One of the women who was a student in Meitner's section at KWI was Tikvah Alper (1930–1933), a South African who would become a prominent radiobiologist and author of the seminal textbook *Cellular Radiobiology* (Alper 1979). Her particular areas of interest included mechanisms of DNA damage, cell survival curves and the influence of dose modifiers, and the nature and movement of viruses within a cell. Alper also had a broad range of expertise and experiences beyond radiobiology, which included training and conducting research related to teaching those without hearing, as one of her sons was born deaf (Hornsey and Denekamp 1997; Sime 2005). After her time at KWI, Alper returned to South Africa and married Max Sterne. Now married, she was unable to attain an academic position, so she and her new husband set up a laboratory in a garden shed at their personal residence. After a few years in England, the couple again returned to South Africa in 1948, when Alper became head of the Biophysics Section of the South African National Physics Laboratory. This appointment lasted until 1951, when she was forced to relocate due to her active and vocal opposition to apartheid. The remainder of her career, as well as her retirement, was spent primarily in England. Happily married (retaining her maiden name) with two children, Alper passed away just shy of what would have been her 63rd wedding anniversary (Hornsey and Denekamp 1997).

Many of the early discoveries involving radiation and radioactivity found medical or commercial use. One of the now infamous examples is the so-called radium boom. For a while, radium was marketed as a medicinal cure-all (Cothern and Smith 1987), and even today, "radon caves" remain a tourist attraction in several areas (Harvie 1999). A second utility emerged when it was discovered that radium could be combined with phosphorescent material to make luminous paint, with related patents filed as early as 1903. The first radium dial watches were sold commercially starting in 1913, followed by a rapid increase in demand for similar radioluminous products through World War I (Rowland 1994). During this time, more than 1,000 workers (nearly 5,000 by 1980), mainly women, painted instruments with radium, licking the brush tip to get a fine point. Although such "tipping" was prohibited starting in 1926, many young women had spent years ingesting radium, in some cases on the order of 40 μg (Fry 1998). The subsequent health effects had a significant historical impact on industrial safety standards, and eventually (1941) a tolerance level for radium was established from dial painter data (Rowland 1994; Clark 1997). Clinical studies of those exposed to radium, particularly dial painters, have resulted in major contributions to the understanding of radium's behavior in the body as well as the disease processes, including tumor formation, that result from ingestion of radium (Boice and Lubin 1997; Fry 1998).

On the medical side, diagnostic radiography also led to some significant exposures. In many instances, it was radiologists and technicians who received the highest doses due to the frequency with which they were exposed. Such exposure may have even contributed to Marie Curie's anemic condition, as she served as a radiologist during World War I (Byers and Williams 2006; Greer and Tolmachova 2011).

Another group with fairly extensive exposures were those being treated for tuberculosis in the mid-1920s through the mid-1950s. Treatment at the time included collapsing the lung with subsequent inspection using x-ray fluoroscopy, which was repeated several times a month for up to 5 y. This resulted in considerable exposure to the chest. The increased risk of breast cancer in groups of such women helped identify the breast as a particularly radiosensitive tissue. Moreover, epidemiological analysis found that fractionation of dose had little impact on the risk of induced breast cancer, that risk of breast cancer remained high for a long time after exposure, and that age was a significant risk factor with younger women being much more susceptible to radiation-induced breast cancer (Miller et al. 1989; Boice et al. 1991). These exposure scenarios are interesting from a risk assessment standpoint, as each examination resulted in a fairly low exposure, but the long-term continuation of said exposures resulted in measureable excess risk. The benefit to the corresponding risk estimates compared to those from high dose scenarios is that they may be more relevant to realistic exposure scenarios, such as those seen occupationally or in diagnostic medicine (Boice et al. 1991).

In 1928, to address the health implications of effects starting to become evident from exposure to radiation, the International X-Ray and Radium Protection Committee (predecessor to the International Commission on Radiological Protection) was established, consisting of only five members (Taylor 1958). The United States Advisory Committee on X-Ray and Radium Protection [predecessor to the National Council on Radiation Protection and Measurements (NCRP)], was established a year later in 1929 (Bushberg 2015).

Pre-war developments: 1930–1945

Although the years leading up to World War II saw significant discoveries and progressions in the radiation sciences, this time was also tarnished by the rapid spread of anti-Semitism (Rhodes 1986). Many scientists of both genders were forced to flee their homes and institutions to escape ethnic persecution. Even the Nobel committee has been accused of interpreting a lack of productivity due to forced emigration as a lack of dedication to the field, coloring the prize results of that time (Sime 2013). World War II also marked the first attack using an atomic bomb. The road to the atomic bomb was remarkably fast, taking only 13 y from the initial discovery of the neutron to fully develop and deploy.

The formal discovery of the neutron was made by James Chadwick in 1932 by adapting experiments conducted by Irène Joliot-Curie (1897–1956) and her husband Frédéric. Irène (Marie and Pierre's daughter) and Frédéric were also close to discovering the positron and nuclear fission, having observed all of these experimentally, but they were unable to formulate a comprehensive explanation of their results. However, the pair were awarded the 1935 Nobel Prize in Chemistry for the discovery of artificial radioactivity (Byers and Williams 2006).

Nuclear fission had been observed by several groups, although it was not identified as such for several years. In 1934, Ida Noddack (1896–1978), a German scientist, was the first person to suggest that the fission event might involve a large atom splitting into smaller atoms. Without a theoretical basis or experimental verification, this prediction was largely ignored (Hook 2003). As an aside, Noddack also played an important role (along with her husband) in the identification of rhenium (1925) and technetium (1933), which have found use in both therapeutic and diagnostic nuclear medicine (Biersack et al. 2015).

Experiments conducted by Otto Hahn in 1938 revealed that Ida Noddack's theory was true; fission did result in the splitting of the atom into fragments. Lise Meitner provided intellectual input regarding these experiments, but having fled Germany 3 mo prior, she was not physically present for their completion. For related political reasons, she was not included on Hahn's corresponding publication. She did provide the comprehensive theoretical explanation for the experimental results in 1939, publishing her results accordingly (Sime 2005). It was this paper that first used the phrase "nuclear fission," which was subsequently adopted by the community as a whole. Hahn alone received the 1944 Nobel Prize in Chemistry for this discovery, even though Meitner had long been his collaborator and her theoretical explanation considered seminal. Despite being nominated several times, she never received a Nobel (Sime 2002).

The Manhattan District began to develop the atomic bomb following Enrico Fermi's demonstration of the first self-sustaining nuclear chain reaction in 1942 at Chicago Pile-1 (CP-1). It was just three short years later that the first atomic bomb was detonated at Trinity Site, followed by the bombings of Hiroshima and Nagasaki 3 wk later (Rhodes 1986).

The Manhattan Project included in its ranks several female scientists as well as numerous female support staff (Rhodes 1986; Howes and Herzenberg 1999; Kiernan 2013). Among them was Leona Marshall Libby (née Woods, 1919–1986), an American scientist who was the only woman in Fermi's group at the University of Chicago (Sanger and Wollner 1995); she was present and reading off her BF_3 counter when CP-1 first went critical. Libby had a long working relationship with Fermi (until his death in 1954) and was heavily involved in both reactor design and plutonium production during World War II (Kiernan 2013).

Katharine "Kay" Way (1902–1995) was also an American nuclear physicist who worked on the Manhattan

Project in Chicago. Her major work focused on neutron fluxes, fission products, and reactor design, but she is primarily known for her innovative methods for data handling and analysis. Way's critical evaluation and analysis of nuclear data (performed in collaboration with Alvin Weinberg) was used in the design and construction of CP-1. Additional theoretical work (in collaboration with Eugene Wigner) led to an empirical equation for fission-product rate of decay, now called the Way-Wigner formula (Martin et al. 1996; Howes and Herzenberg 1999).

The Manhattan Project also gave rise to the early days of health physics. Jane Hamilton Hall (1915–1981), a physicist by training, was placed in the radiation protection group at Hanford during her time on the project because her husband David was also a physicist, and a married couple could not be in the same division. Hall worked on plutonium inhalation hazards, instrumentation development, and monitoring of staff. She spent latter part of her career primarily at Los Alamos National Laboratory working on a variety of projects (Howes and Herzenberg 1999).

Although much of the work during this time contributed to the development of peaceful nuclear power as well as the atomic bomb, work was also being done with other applications in mind. For example, nuclear medicine began to grow as a field, with Edith Quimby (1891–1982), an American medical physicist, considered as one of its founders. She pioneered various brachytherapy and internal dosimetry systems, and even added physics to the American Board of Radiology examination in 1936 (Linton 2012). In 2011, the American Association of Physicists in Medicine (AAPM) named the Edith H. Quimby Lifetime Achievement Award in her honor (Rothenberg 2015).

Marietta Blau (1894–1970) was an Austrian-born Jewish physicist who did quite a bit of work in fundamental particle physics. She worked for more than a decade at the Radium Institute in Vienna, although her position was unpaid. The first two directors of the Radium Institute were known for supporting and encouraging women in science, with nearly a third of the scientists at the institute being women. Blau pioneered the use of photographic methods for imaging high-energy nuclear particles and events, such as those originating in cosmic radiation (Byers and Williams 2006; Sime 2013). Protons were of particular interest to Blau, and following the discovery of the neutron, she was able to quantitatively determine incident neutron energy through the resultant tracks of recoil protons. Her most famous accomplishment was that she, with her associate and former doctoral student Hertha Wambacher (1903–1950), discovered "disintegration stars" in 1937, paving the way for the discovery of the pion. Blau and Wambacher were both nominated for the 1950 Nobel Prize in Physics by Erwin Schrodinger, which controversially went only to Cecil Powell for his follow-up work with photographic emulsions and the discovery of the pion. Blau was nominated at least twice more for the Nobel but never received one; although there was evident, purposeful omission of Blau from genuine consideration for these awards, it is unclear whether this is based in gender or ethnicity (or a combination of both). Blau's situation was more difficult than most, as Wambacher and at least three other of her colleagues were members of the Nazi party and actively worked against her starting in the early 1930s. Blau left Vienna the day before Austria was annexed into the German Reich. From then on, the remaining physicists at the Radium Institute attempted to obscure any contributions Blau made, even blatantly taking some of her work as their own (Byers and Williams 2006; Sime 2013).

The Atomic Age: 1945–1980

The Atomic Age was the time of the Cold War, with many atomic weapons tested in the atmosphere, underground, and underwater throughout the world. However, this time also saw many other advancements in the radiation sciences, from fundamental principles to medical applications. This section reflects such variety as new and different branches of nuclear science begin to form.

Gertrude "Trude" Scharff Goldhaber (1911–1998) was a German physicist who experienced tremendous personal hardship in her lifetime, from having to eat bread made with sawdust during World War I to enduring her parents' death in the Holocaust in World War II (Bond and Henley 1999). She left Germany in 1935 as soon as she finished her Ph.D. and ultimately ended up in the United States at the University of Illinois. The interpretation of nepotism laws at the time prevented the hiring of spouses, so Goldhaber's only option for work was to take an unpaid position in her new husband's laboratory and shift her research focus to his field: nuclear physics (her dissertation focus was in magnetism). It would be 15 y post-doctorate before Goldhaber would receive a regular, paid position on the staff at Brookhaven National Laboratory (BNL). She nonetheless flourished and is said to have been very cheerful. One of her early accomplishments was the discovery that spontaneous fission is associated with the emission of neutrons (1942), although this finding was held back until after the war. In collaboration with her husband, she also demonstrated that beta particles emitted in radioactive decay are identical to electrons (1948) (Bond and Henley 1999; Byers and Williams 2006). Some of her later work in nuclear physics was conducted in collaboration with her son, potentially the first of that particular familial pairing in physics collaborations. Brookhaven National Laboratory awards the Gertrude and Maurice Goldhaber Distinguished fellowship to early career scientists in the couples' honor (BNL 2016).

Chien-Shiung Wu (1912–1997) was a Chinese-American scientist who is regarded as a founder of nuclear and particle physics. She made many contributions to the Manhattan Project (1944–1945), including providing insight into the reactivity loss experienced by Hanford reactors (Byers and Williams 2006). Wu's doctoral work (conducted at the University of California at Berkeley) focused on determining various properties of uranium fission products, through which she identified two isotopes of xenon (Xe), and her data was used to confirm ^{135}Xe as a reactor poison. Moreover, these data contributed to the reactor design process and the development of operational strategies that became a critical contribution to the Manhattan Project (Howes and Herzenberg 1999; Lidofsky 2001; Benczer-Koller 2009). Most of Wu's career was spent at Columbia University, where she initially worked on the gaseous diffusion process for uranium enrichment. She transitioned to researching beta energy spectra, performing elegant experiments that definitely confirmed the theoretical explanation for beta decay first suggested by Wolfgang Pauli in 1930 and later modified and elaborated upon by Fermi in 1933 (Jiang and Wong 2014). She is perhaps best known, however, for her experimental work that proved parity is not conserved in beta decay (theorized by Tsung-Dao Lee and Chen Ning Yang), publishing the seminal paper in 1957. The theorists were awarded the 1957 Nobel Prize in Physics (Jiang and Wong 2014), but Wu was not included. Wu became the first female president of the American Physical Society in 1975 (Benczer-Koller 2009).

A charter member and the fourth president (1959–1960) of the Health Physics Society (HPS), Elda "Andy" Anderson (1899–1961) was an American physicist who was instrumental in the formation of the HPS as well as the establishment of professional certification for health physicists in the United States (Morgan 1965; Moeller 1972). After working on the Manhattan Project, she became the first chief of education and training in the Health Physics Division at Oak Ridge National Laboratory (ORNL) in 1949 and was well known for being a dedicated teacher and mentor. The Health Physics Society established the Elda E. Anderson Memorial Fund in her honor, from which the Elda E. Anderson Award was formed. This award has evolved to annually recognize a young member of the society for distinguished contribution to the profession of health physics (Kathren and Tarr 1974). Ironically, the first 30 y following the award's inception saw no female recipients; the first woman to receive the award was Kimberlee J. Kearfott (currently a professor in the Department of Nuclear Engineering and Radiological Sciences at the University of Michigan) in 1992 (Kearfott 1992). Anderson's appointment at ORNL happened to coincide with the establishment of the Mammalian Genetics Section (Mouse House) at ORNL, led by Liane "Lee" and Bill Russell. Among their many accomplishments was the demonstration of both dose-rate effects and radiation-induced hereditary effects in mice. In addition to Lee Russell, many of the support staff, particularly technicians, were also women (Russell 2013). Oak Ridge National Laboratory currently awards an early career fellowship named in Lee Russell's honor (ORNL 2016).

The Oxford Survey of Childhood Cancers was initiated in 1956, led by Alice Stewart, M.D. (1906–2002). Although much of Stewart's work remains controversial (Greene 1999; Wakeford 2000; Bithell 2002), this particular study was the first to bring attention to the potential risks of in-utero exposure to ionizing radiation and thus resulted in the general adoption of alternate obstetric imaging modalities (Boice and Miller 1999).

Maria Goeppert Mayer (1906–1972) was a Polish-American physicist who was the second, and only, woman behind Marie Curie to win the Nobel Prize in Physics (1963) for the 1948 discovery of magic numbers and development of the nuclear shell model. Her portion of the prize was shared with J. Hans Jensen, as they each independently proposed the nuclear shell structure of the atomic nucleus in the late 1940s. The American Physical Society created the Maria Goeppert Mayer Award in 1986 in her honor as an annual recognition of an outstanding early career female physicist (Byers and Williams 2006).

The NCRP in the United States was formally chartered the following year (1964). Both Edith Quimby and Rosalyn S. Yalow were among the charter members (Bushberg 2015). The International Radiation Protection Association (IRPA) began formation the same year and was officially established in 1965 with its first congress subsequently held in 1966 (Webb 2011).

Rosalyn "Ros" Sussman Yalow (1921–2011) was a nuclear physicist whose research focused on medical applications of radioisotopes. She became the first American woman to win the Nobel Prize in Physiology or Medicine (1977), awarded for developing radioimmunoassay (RIA) and which she shared with her long-time collaborator and friend Solomon Berson (Bauman and Langhoff 2011; Kahn and Roth 2012). RIA has found wide-ranging, far-reaching applications, from drug measurement and delivery to investigation of infectious diseases; RIA was truly revolutionary, but rather than patent their discovery, Sussman and Berson made every effort to make RIA accessible to anyone interested (Bauman and Langhoff 2011).

In 1972 Margaret Butler (1924–2013), an American mathematician and computer scientist, became the first female fellow of the American Nuclear Society. Her career was largely spent dedicated to the computational aspects of the various facets of nuclear energy. Argonne National Laboratory awards a computational science fellowship to early career scientists in her honor (ANL 2013).

Patricia Durbin (1927–2009), an American biophysicist, developed what has come to be referred to as the

Durbin model for plutonium excretion in 1972, using data from human injection studies conducted by the U.S. government in the 1940s (Durbin 1972; USDOE 1994). As an aside, Title IX of the Educational Amendments, which banned gender discrimination in federally-funded educational institutions, was signed into law in the United States the same year (1972) (Walters and McNeely 2010). Durbin's career focused largely on biodistribution and biokinetic models of various radionuclides, and she also made significant contributions in the development and improvement of chelating agents (USDOE 1994). Durbin is one of only three women to date to have given the Lauriston S. Taylor lecture (initiated in 1977) at the annual NCRP meeting (2007), behind Naomi Harley (1999) and prior to Eleanor Blakely (2011) (NCRP 2016).

Also in 1972, Dixy Lee Ray, a marine biologist by training, became the first female and last person to chair the U.S. Atomic Energy Commission (AEC) (Ellis 2005). The AEC was abolished in 1974 in favor of splitting its responsibilities between different organizations to avoid a perceived conflict of interest (ultimately, these were the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy) (USDOE 2016). Ray was also the first female governor of Washington, taking office in 1977. A colorful, and at times controversial, character, Ray was a strong proponent of public education in the sciences as well as the use of nuclear energy (Ellis 2005). The American Society of Mechanical Engineers (ASME) established the Dixy Lee Ray Award in 1998 in honor of Ray's dedication to engineering solutions for environmental issues. The award is given annually in recognition of outstanding contributions to the field of environmental protection (ASME 2016).

The recent years: 1980s–2010s

From the late 1940s, radiation protection began to evolve to be its own diverse field. In recent years, the number of women actively pursuing careers in radiation protection and making significant contributions has increased dramatically, happily more than can be included here. As opposed to specific scientific contributions, then, this section focuses on the progress women have made in terms of leadership positions within selected sections of the current community.

Z.M. "Nettie" Beekman (1927–2013), originally trained as a medical doctor and radiologist, was the first female (and fifth overall) president of IRPA, serving from 1980–1984 (Webb 2011). She was also one of the founding members of the Dutch Society of Radiation Protection (1960) and is known for being essential to the development of radiation protection in the Netherlands (Boersma 2014). The second female IRPA president behind Beekman was Renate Czarwinski, who took office in 2012, some 30 y later (IRPA 2012). Also in international leadership is Claire Cousins, an interventional radiologist from the United Kingdom. Taking office in 2009, she is the current chairperson of the ICRP and the first woman ever to hold the position (ICRP 2016).

In the United States, E. Gail de Planque was a nuclear physicist and health physicist who became the first woman to serve as a Commissioner (1991) of the U.S. Nuclear Regulatory Commission (NRC). She was also the first female president of the American Nuclear Society (1988). Her specialties included, among others, environmental radiation metrology and dosimetry (Cox et al. 2011). Shirley Ann Jackson is a theoretical nuclear physicist and the current president of Rensselaer Polytechnic Institute. She was the first African American woman to earn a doctorate from the Massachusetts Institute of Technology (1973) and was the first female to serve as chairperson of the NRC (1995–1999) (RPI 2012).

The year 2011 saw the tragic natural disaster and subsequent nuclear accident at Fukushima-Daiichi. Although scientists researching in Fukushima are predominantly male, it is often women leading community support and education initiatives, from public health professionals to community members (ICRP 2015). One of the most notable of these women is Ryoko Ando, of Fukushima Ethos, who is very active in promoting the collaborative yet autonomous recovery of the area (Ando 2016).

FINAL THOUGHTS

There are many women, and many accomplishments, not captured here, and there are also undoubtedly many women whose accomplishments have been lost in the pages of history. The hope, however, is to have presented an interesting timeline from a perspective not often seen in radiation protection. Although there has been tremendous progress in societal reception of women in science since the discovery of radiation and radioactivity, and subsequently the number of women in the field, gender representation remains uneven, seemingly due to lingering issues associated with prior history of discrimination and stereotypes (Gillenwalters and Martinez 2017). Most of the women mentioned here came from supportive families and/or had supportive colleagues, which is a tradition that will continue to be important in the inclusion and encouragement of young women (and men) across disciplines. That is, there will always be a continued need for recognizing and communicating that gender does not limit one's potential.

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