

HISTORY OF PIONEER WOMEN IN MEDICAL PHYSICS

Azam Niroomand-Rad^{1,3} , Slavik Tabakov^{2,4}

¹Medical Physics Department, University of Wisconsin, Madison, Wisconsin, USA

²Department of Medical Engineering and Physics, King's College, London, UK

³ IOMP President (2003-2006), ⁴IOMP President (2015-2018)

Abstract:

In celebration of the 60th Anniversary of the International Organization for Medical Physics (IOMP), it is important to recognize and acknowledge women who have made great contributions to the advancement of medical physics (MP). The authors believe that contributions of outstanding female medical physicists in IOMP Regional Organisations may inspire young women to enter medical physics profession. This is especially important for the benefit of future female medical physicists who wish to participate in improving status of women medical physicists worldwide. In this pursuit, young female medical physicists need to be mindful of experiencing some challenges and obstacles in reaching their potentials. The paper discusses developments in the period before 2018 and lists bios of some pioneering women medical physicists from the Regional Organizations of IOMP.

Keywords: Physics, Medical Physics, Medical Engineering, Science, Women Medical Physicists, IOMP, AAPM

1. Introduction:

Physics is not a list of facts about the world. History is not a list of names and dates of what happened in the past. It can be a powerful tool to illuminate the path to future. Scientists adopt and adapt various approaches as new challenges arise. Contributions of scientists are built on the shoulders of those who came before them. They have a role to play in making our world healthier. Each leader identified a problem they wanted to solve and developed a plan to do so.

The history of Medical Physics (MP) is short relative to that of most recognized academic and professional specialties. The rapid growth of Hospital Physicists Association (HPA) in UK in 1940s and American Association of Physicists in Medicine (AAPM) in 1958, led to the formation of International Organization for Medical Physics (IOMP) in 1963. With establishment of European Federation of Organizations for Medical Physics (EFOMP-1980), Association of Latin American Physicists in Medicine (ALFIM-1984), Asia-Oceania Federation of Organizations for Medical Physics (AFOMP-2000), South-East Asian Federation of Organizations for Medical Physics (SEAFOMP-2000), Middle East Federation of Medical Physics (MEFOMP-2009), and Federation of African Medical Physics Organizations (FAMPO-2009), currently IOMP includes about 30,000 medical physicists globally [81].

During the first 30 years after the establishment of IOMP (1963-1993), the number of medical physicists worldwide grew from c.6,000 to about 12,000 members worldwide. However, during this period, the leadership of the Organization (with elections each 3 years) did not include women.

In 1994 IOMP leadership included Ann Dixon-Brown, (UK) as Treasurer and Azam Niroomand-Rad (USA) as Editor-in-Chief of the IOMP Bulletin Medical Physics World. In 1997 IOMP elected Azam Niroomand-Rad as Chair of the Education and Training Committee (ETC). In 2000 Azam was elected as IOMP Vice-President and Nisakorn Manatrakul (Thailand) was elected as Treasurer. In the period 2003-2006 Azam Niroomand-Rad took the position as the first woman President of IOMP. One of Azam most important activities was working with ILO (International Labor Organization) towards recognition and inclusion of Medical Physicists in the International Standard Classification of Occupations (ISCO-2008) – an activity of special importance for the acceptance of the MP profession in many countries. This admission opened many doors to women medical physicists (WMPs) in Health Professionals and health services in developed and developing countries.

During the following years the number of women in the leadership increased and in different periods important IOMP Committees were chaired by women: Science Committee (SC) by Caridad Borrás (Spain, USA); Education and Training Committee (ETC) by Anchali Krisanachinda (Thailand) and Maria do Carmo Lopes (Portugal); Awards and Honours Committee (AHC) by Simone Kodlulovich Renha (Brazil); Medical Physics World Board (MPWB) by Virginia Tsapaki (Greece), Magdalena Stoeva (Bulgaria), Chai Hong Yeong (Malaysia); Professional Relations Committee (PRC) by Simone Kodlulovich Renha (Brazil). Moreover, Dr Borrás (Spain, USA) and Dr Simone Renha (Brazil) supported many activities in development of the MP profession in Latin America.

Since then, Dr Krisanachinda (Thailand) was one of the main contributors for the development of the profession in South-East Asia. Dr Tsapaki (Greece) and Dr Stoeva (Bulgaria) moved the IOMP Bulletin Medical Physics World (MPW) to new heights and increased dramatically its readership. They both played a very important role for the establishment and promotion of the IOMP Women Sub-Committee (WSC) in 2014. Dr Tsapaki became the first Chair of the WSC and Dr Stoeva prepared WSC website. In 2016, during the International Conference of Medical Physics (ICMP 2016, Bangkok) the IOMP WSC organized two women symposia. In 2018, several activities and Webinars were organized by IOMP Women Sub Committee (WSC).

During 2015-2018 the IOMP leadership (ExCom with 11 elected members, President S Tabakov) included four women with Dr Virginia Tsapaki (Greece) as the first woman IOMP Secretary-General; Dr Anchali Krisanachinda (Thailand) as Treasurer; Dr Simone Kodulovich Renha (Brazil) as Chair AHC, and Dr Magdalena Stoeva (Bulgaria) as Chair of MPWB.

In 2012, the IOMP ExCom established the International Medical Physics Day (IDMP) which was decided to be celebrated on 7 November each year in honor of Maria Skłodowska-Curie (her birthday being on Nov. 7, 1867). The first celebration of IDMP was in 2013, in connection with the IOMP 50th Anniversary of IOMP, which included a special poster with her photo, as a patron of the profession. The IDMP in 2017 was a special celebration of the 150th Birthday of Marie Curie.

Despite this steady growth, the number of female medical physicists in leadership roles was small. This article traces the first steps of promotion of women in medical physics (WMP) in IOMP and its Regional Organizations. Importantly this article also includes a review of female scientists who made major contributions in physics with application to medicine and medical physics, as well as leading women scientists medical physicists who contributed to the global advancement and development of the MP. These leaders served (and are serving) as role models to generation to come after them.

2. Life and Achievements of Women Scientists in New Physics

2.1 Maria Skłodowska-Curie Polish and naturalized French physicist and chemist (Nov. 7-1867 – 1934). She was the first woman scientist who received Nobel Prize in Physics (1903) and in Chemistry (1911) – hence the first woman (and the first scientist) who received two Nobel Prizes.

Maria Skłodowska-Curie was born in Warsaw, Poland in 1867. She is an inspiring scientist to many female scientists who came after her. Maria entire life, from the very beginning of her scientific career, exemplifies profound struggles and many obstacles that she had to overcome in her life in Poland, in her journey from Poland to France and her life in her adopted country. She wanted to understand the laws of nature that led to the discovery of new elements and eventually the creation of a new branch of science, radioactivity, a term that was coined mainly by her. She was a genius believing “Nothing in life is to be feared – it is only to be understood.”

In 1903, Curie became the first woman to earn a PhD in physics and the first woman to become professor in France. The professors who reviewed Maria’s doctoral thesis about radiation, said “it was the greatest single contribution to science ever written”. However, being a female, she was not allowed to present the result of her research, to the French Academy of Sciences. She never stopped her scientific work and declined to apply to the Academy since it was not open to women.

Marie Curie became the chair of physics at the Science Faculty of the University of Paris after the sudden death of her husband Pierre Curie in 1906. Her scientific research (1886-1909) was under difficult laboratory condition, but when she received her first Nobel Prize in physics (1903, shared with P Curie and H Becquerel), her working conditions gradually improved during 1909-1915. When she received the second Nobel Prize in chemistry (1911), she headed the Radium Institute in Paris (1915-1934), overseeing physics and chemistry research.

Marie Curie published her famous book “The Treatise of Radioactivity” in two volumes that were valuable textbook for young researchers. This led to rapid development of science of radioactivity. Marie Curie’s last great work was her third book “Radioactivity”. Under Maria Curie’s leadership, the Institute of Radium in Paris rose to a leading position in the development of the science of the radioactivity of matter and structure of the atomic nucleus.

When appraising Marie Curie's own work and those done under her supervision, it is clear that she was able to master extensive knowledge in both physics and chemistry. Within less than 25 years after the discovery of polonium and radium, several radioactive elements were discovered in uranium-radium series, thorium series, and actinium series. One of Marie Curie's greatest admirers was Albert Einstein who said "Not only did she do outstanding work in her lifetime, and not only did she help humanity greatly by her work, but she invested all her work with the highest moral quality. All of this she accomplished with great strength, objectivity, and judgement. It is very rare to find all these qualities in one individual."

During World War I (WWI, 1914 -1918), Marie Curie faced new challenges. Marie was a patriot and used the money from her second Nobel Prize to buy war bonds to support the French army. She recognized that wounded soldiers were best served if operated as soon as possible. She saw a need for field radiological centers near the front lines to assist battlefield soldiers. After a quick study of radiology she prepared a vehicle with X-ray equipment and auxiliary generator and created mobile radiography units, known as *petites Curie* ("Little Curies").

In 1920, Marie Curie granted a rare interview in her laboratory in Paris to Mrs Meloney, who was editor of the USA journal - *The Delineator*. During this meeting, Mrs Meloney learned that Marie Curie who had freely given radium away for patients to be treated, had no financial means to acquire additional radium to continue her laboratory research. Mrs Meloney promised Maria to help. When she returned to US, she launched extensive campaign to raise money (\$100,000) from the Women of America.

On May 12, 1921, Marie Curie accompanied by her two daughters, Irene (24) and Eve (17) came to USA and they were greeted by Mrs Meloney. On May 20, 1921, at invitation of President Harding, she went to the White House to receive the gift of 1 gram of radium from President Harding. The hazardous source itself was not brought to the ceremony and instead, she was presented with a certificate and a golden key to a safe box with 1 gr of radium. Marie Curie died in 1934 of aplastic anemia, most likely of exposure to radiation and X-rays in pursuit of her scientific research and work in hospitals during WWI. Marie Curie was the first woman to be buried in the Panthéon in Paris on her merit. [1, 2, 3, 4, 5, 6]

2.2 Irene Joliot - Curie (1897-1957) – French Chemist, Nobel Laureate (1935)

Irene was born in Paris in 1897. She was the older daughter of Maria and Pierre. She was 8 years old when she lost her father in a tragic accident. Irene was not told what happened to her father until after his funeral. Maria sense of self-respect and hard work was transferred to Irene. When WWI started, Irene, a young teenage, accompanied her mother and took part in the war-related activities described above.

After WWI, Irene returned to Paris and worked as her mother's assistant at the Radium Institute. In 1925, Irene received her doctorate. Her doctoral thesis was on alpha particles emitted by radioactive polonium during its disintegration. In particular, she focused on how alpha particles decelerate while moving through matter. Irene's expertise in dealing with this element was exclusive. Her dissertation defense made it to international News media.

Soon after the discovery of radium in 1903, the Curies observed that all substances close to a strong radium sample became active. They referred to this phenomenon as *induced radioactivity*. When Irene worked at the Radium Institute, she showed that a certain type of nuclear transmutation led to the formation of radioactive species that became known as *artificial radioactivity*.

It was at the Radium Institute that Irene met her husband, Frederic Joliot. Irene and her husband worked together, focusing their research on the atomic nuclei structure. In their experiment, they placed their polonium next to an aluminum foil. They expected hydrogen nuclei to emerge, but instead they observed that neutrons and positrons appeared. With a Geiger counter, they confirmed that the aluminum foil had become radioactive. Therefore, Irene and Frederic were the first scientists to artificially produce a radioactive element. This discovery had a great impact in producing radioactive materials for cancer treatment.

In 1934, the last year of Marie Curie's life, she knew that Irene and her husband had acquired great fame and repute because of their discovery. In 1935, Irene and her husband received Nobel Prize in Chemistry thus making Maria and Irene the only two mother-daughter pair to have won Nobel Prizes. When Albert Einstein was in Paris, he said "Madam Curie was fortunate to see her work to be continued by her daughter, who was her equal in talent and scientific activity".

In the early 1930s, the whole world started paying attention on French research because of the scientific contributions by Maria Curie, Irene, and Frederic. However, years of working so closely with radioactive materials finally caught up with Irene and she was diagnosed with leukemia. She had been accidentally exposed to polonium when a sealed capsule of the element exploded on her laboratory bench in 1946. Despite this incident Irene continued her work and drew plans for new physics laboratories at Faculty of Sciences in 1955 which is now part of Paris University. Irene and Frederic had two children: Helene Joliot (born 1927) and Pierre Joliot (born 1932). [7, 8, 9, 10, 11]

2.3 H el ene Langevin-Joliot (1927) – French Nuclear Physicist

H el ene Langevin-Joliot-Curie, daughter of Irene Joliot-Curie was born in Paris, France in 1927. She may be a descendent of one of the most honored families in the history of science. H el ene professional contributions to the scientific world have rightly earned her own place in history. She is known for her research on nuclear reactions in French laboratories. She was particularly skilled in math and sciences. When growing up H el ene was encouraged by her parents to study physics which is the field she pursued.

In her teens, H el ene studied at the Ecole National de Chimie Physique in Paris. Later she studied at the Institute of Nuclear Physics and Particle Physics at Orsay where she excelled academically. After receiving her bachelor's degree, she began her doctorate in nuclear physics focusing on auto ionization and internal Bremsstrahlung phenomena. In 1948 H el ene married the physicist Michel Langevin (grandson of the physicist Paul Langevin).

In 1949, after receiving her doctorate, Prof Helene Langevin-Joliot worked as researcher at the French National Center for Scientific Research (CNRS), focusing on nuclear reactions. In 1969, Helene became Director of research at CNRS until she retired in 1992. Upon her retirement, she became Emeritus Director of Research at CNRS.

During 1949 – 1957, Prof H el ene Langevin-Joliot worked at the Laboratory of Chemistry and Nuclear Physics at the College de France. During 1957-2008, she worked on nuclear reactions for the Institute National de Physique Nucleaire et de Physique des Particules. Toward the end of her professional career, she worked for the French Government Advisory Committee.

During 1985-1992, Prof H el ene Langevin-Joliot was a member of the Scientific Advisory Group of the Parliamentary Office and Technological Options. She was also a member of the Commission for the Centennial Celebration for the Discovery of Radioactivity. She was also professor of nuclear physics at the Institute of Nuclear Physics at the University of Paris. She is actively involved in encouraging women to pursue careers in scientific fields.

In 1997, when celebrating 100 years discovery of Radium, Azam Niroomand-Rad met Prof H el ene Langevin-Joliot in Nice, France. When Azam asked H el ene if the physics “gene” has been passed on to her children, H el ene smiled and responded, “her son, Yves Langevin (born 1951), is an astrophysicist”.

Since 1997 Prof H el ene Langevin-Joliot and Azam Niroomand-Rad have been in communication. In April 2003, Azam invited H el ene to come to USA and give some lectures to medical and medical physicists at Georgetown University School of Medicine, in Washington DC. At the time, Azam also invited H el ene’s aunt, Eve Curie (1904-2007) who was living in New York City to come to Washington DC to visit us. When Azam talked to Eve, she found her very active and alert, despite her age. Eve declined Azam’s invitation due to some health issues.

On April 11, 2003, Prof H el ene Langevin-Joliot was interviewed by Azam on behalf of IOMP, AAPM, and American Institute of Physics (AIP), Center for History of Physics at College Park, Maryland, USA. The video interview is available at AAPM Heritage Archive. A few years later in 2009, when Azam Niroomand-Rad received IOMP **Maria Sklodowska-Curie** Award at World Congress in Munich Germany, H el ene invited Azam to her home in Paris. H el ene enthusiastically shared many fond memories of her parents and grandparents at her home. H el ene also took Azam for a visit of Curie laboratory in Orsay Paris. [12, 13, 14, 15, 16]

2.4 Lise Meitner (1878-1968) – Eminent Austrian-Swedish physicist

Lise Meitner received her doctorate in physics from the University of Vienna in 1906 and was the second woman to earn a doctorate in physics. She spent most of her scientific career in Berlin, Germany, where she was a physics professor and a department head at the Kaiser Wilhelm Institute. She was the first woman to become a full

professor of physics in Germany. She lost her position in the 1930s because of the rise of anti-Jewish Nuremberg Laws of Nazi Germany.

In 1938 Prof Lise Meitner fled to Sweden, where she lived for many years, ultimately becoming a Swedish citizen. In 1939 Lise Meitner published her discovery that atomic nuclei split during some uranium reactions. She was the first to describe and coin the term “*nuclear fission*” in her scientific paper. Prof Lise Meitner groundbreaking research led to understanding of nuclear fission and eventually to design of the atomic bomb - hence she was known as “Mother of Atomic Bomb”.

Prof Meitner was nominated numerous times for the Nobel Prize (in physics and chemistry) by many eminent scientists, but did not receive Nobel Prize. Prof. Lise Meitner is among those most often cited as having been unfairly overlooked. Albert Einstein once called her the “*German Marie Curie*.”

Sadly, Prof Meitner was rarely lauded for her critical contributions to physics and chemistry at the time of their novelty. Despite not having been awarded the Nobel Prize, she was invited to attend the Lindau Nobel Laureate Meeting that was founded in 1951 in Lindau, Germany. She received many honors, including the name of element meitnerium (Mt) with atomic number 109 that had similar properties as iridium. After Prof Meitner death in 1997, International Astronomical Union (IAU) named a Crater in Venus in her honor. [17, 18, 19, 20]

2.5 Maria Goeppert Mayer (1906-1972) – German American Physicist, Nobel Laureate (1963)

Maria Goeppert was born in Kattowitz, Germany in 1906. She grew up in Gottingen, Germany where her father was a pediatrics professor at George-August Universitat. Maria was very close to her father who encouraged her to pursue higher education. In 1914, when she was 8 years old, WWI (1914-1918) started and hence there was a shortage of food. But when WWI ended, Maria was a young woman ready to resume her education. Even though Maria excelled in mathematics, her teachers doubted if Maria could go to university.

However, in 1924, Maria Goeppert became more interested in physics especially after she met Max Born, a theoretical physicist who was developing quantum mechanics. Max Born encouraged Maria to take physics courses which she did until she finished her doctorate in 1930. During this period, Maria faced financial difficulties especially after her father died. Despite many hardships, Maria was happy to meet her future husband, Joseph Mayer, an American researcher from California, who was at Göttingen to study quantum mechanics. Maria’s husband did not want her to quite her career after marriage.

Before and during World War II (WWII, 1939-1945) Germany was under Nazi dictatorship. Therefore, Maria and her husband had to move to Baltimore, Maryland, USA. However, Maria could not get a position at John Hopkins University where her husband was employed. Moreover, Maria’s life became more difficult when her children were born in 1933 and 1938.

With rise of WWII-related sentiments in USA, Maria’s husband lost his job at John Hopkins. But soon after he was employed to teach chemistry at Columbia University in New York City, NY. Maria was also employed to teach mathematics and work for Manhattan Project group that were doing research and development. They produced the first nuclear weapons and created atomic bomb. Maria’s work was to design an efficient way to separate uranium-235 from uranium-238.

When WWII was over in 1945, Maria worked at the Institute for Nuclear Studies at the University of Chicago in Illinois. She studied why some isotopes were more stable than others. In 1960 when family moved to California, Maria at age 53, finally became a professor at the University of California in San Diego, CA. Maria continued her research in double-photon emission theory, that was the subject of her doctoral thesis.

In 1956, Prof Maria Goeppert Mayer became a member of the National Academy of Sciences in the USA and a corresponding member of the Akademie der Wissenschaften in Heidelberg, Germany. In 1963 Maria Goeppert Mayer received the Nobel Prize in physics for proposing the nuclear shell model of the atomic nucleus. Maria died in 1972 in San Diego. Later, in Maria’s honor, an award was created under her name by the American Physical Society for young women physicists [21, 22, 23, 24].

2.6 Rosalyn Yalow (1921-2011) – American Nobel Laureate in Medical Physic (1977)

In 1921 Rosalyn Yalow was born to Jewish parents in the toughest neighborhood of Bronx in New York City, NY. She studied physics at Hunter College in New York City. She then worked as a secretary for Dr. Rudolf Schoenheimer who was a leading German American biochemist in Columbia University College of Physicians and Surgeons. She also worked as a secretary to Michael Heidelberger who was a famed biochemist working in immunology.

A few years later, Yalow was offered a teaching assistant position in physics at the University of Illinois at Urbana-Champaign. She received this offer partially because WWII (1939-1945) had just begun, and many men had to go to war. The University decided to admit women and offer them education and jobs to avoid shut down.

Yalow was the only woman among the department's 400 members and the first woman since 1917. Being surrounded by gifted men made her aware of a wider world in science. They recognized her talent, encouraged her, and supported her to succeed. However, Yalow felt that some women did not like her research ambition in physics since she did not want to be schoolteacher, the usually acceptable path for a woman in science at the time.

In 1945 Yalow earned her PhD at the University of Illinois at Urbana-Champaign. In 1946, she returned to Hunter College in NY to teach physics at the New York University. Her first job was an assistant electrical engineer at the Federal Telecommunications Laboratory. She again found herself to be the only woman employee. She remained a physics lecturer from 1946 to 1950. In meanwhile in 1947, Yalow began her long consulting association with the Bronx Veteran's Administration (VA) Hospital that were interested in establishing research program for medical uses of radioactive substances. Finally, Yalow left her teaching job and became a fulltime researcher at the VA in 1950.

At the Bronx VA Hospital she developed radioimmunoassay, a radioisotope tracing technique for measurement of tiny quantities of various biological substances in human blood as well as a multitude of other aqueous fluids. Without Yalow contributions in accurate hormone measurement, it was impossible to diagnose various hormone-related conditions and endocrine diseases like type 1 diabetes. Despite its huge commercial potential, Yalow refused to patent the method.

In 1968, Yalow was appointed as a research professor in the Department of Medicine at Mount Sinai Hospital, where she later became the Solomon Berson Distinguished Professor at Large. Yalow had a passion for the next generation of researchers, and she was a mentor figure to scientists from around the world, many of whom came to share her passion for investigative endocrinology research. In this way, Yalow's legacy in endocrinology was carried on and she was referred to as "The Mother of Endocrinology."

Prof Yalow received many awards from various organizations including Award from the American College of Physicians recognizing her contribution to internal medicine. In 1972, Yalow was awarded the William Middleton Award for Excellence in Research, which is the highest honor awarded annually by the Biomedical Laboratory Research and Development Service to senior biomedical research scientists in recognition of their outstanding scientific contributions and achievements, pertaining to the healthcare of veterans. In 1972, Yalow received the Koch Award of the Endocrine Society, that was designated for individuals for dedication to excellence in research, education, and clinical practice in the field of endocrinology.

In 1977, Yalow was the fourth female scientist and the first American-born woman, to receive the Nobel Prize in a scientific field. She was also the second woman in the world to receive Nobel Prize in the physiology or medicine category - the first was Gerty Cori who received Nobel Prize in 1947.

Prof Yalow also received the Golden Plate Award of the American Academy of Achievements. In 1978, she was elected a Fellow of the American Academy of Arts and Sciences. In 1986, Yalow was awarded the A. Cressy Morrison Award in Natural Sciences of the New York Academy of Sciences. In 1988, Yalow received the National Medal Award that is given to an American who deserve the highest honor in science and technology. In 1998, Prof Yalow was inducted into the National Women's Hall of Fame. In 1998 Prof. Yalow was interviewed by Prof Azam Niroomand-Rad and Prof. Robert Gorson at her home in New York City, NY. [25, 26, 27, 28]

3. Pioneering Women from North America with Leading Roles in Advancement of Physics as applied to Medical Physics

3.1 Harriet Brooks (1876-1973) – First Nuclear Physicist in Canada

Harriet Brook was born in 1876 in Exeter, Ontario, Canada. Harriet's father was struggling to feed his family and provide education to his nine children. Only Harriet and her younger sister were able to continue their education after high school. In 1894 when family settled in Montreal, Harriet completed her education at the Seaforth Collegiate Institute in Seaforth Ontario. Harriet's mother encouraged her to pursue her education and to enroll in McGill University in Montreal.

Harriet was an outstanding student and supported herself by winning scholarships and awards every year. At college Harriet studied mathematics for the first two years and physics for the last two years. In 1898, Harriet completed her college education with high honors in mathematics and physics. She was also awarded a teaching diploma that was given to women graduates to be encouraged to become schoolteacher.

Harriet was very talented and right after her college education, she was hired by Ernest Rutherford who had gone to McGill University (from 1897 to 1907) to establish a laboratory for nuclear physics research. Rutherford had become known as "father of nuclear physics" when he had received the Nobel Prize in Chemistry (1908).

Harriet studied radioactive materials at the laboratory in McGill University. When Rutherford returned to England, Harriet followed him and worked under J.J. Thomson at the University of Cambridge. At Rutherford's Cavendish laboratory, Harriet continued her studies on radioactivity and after a year she returned to Canada and joined Royal Victoria College at McGill University as a tutor in physics.

In 1904, Harriet went to USA and became a faculty at the Barnard College, a women's college that was affiliated to the University of Columbia in New York City. In 1906, Harriet got engaged with a physics professor from Columbia University. But the Dean at Barnard College asked Harriet to resign arguing that "she cannot be both married and a successful academician". Harriet wrote to the Dean saying: "I think it is a duty I owe to my profession and to my sex to show that a woman has a right to practice her profession and cannot be condemned to abandon it merely because she marries". Harriet broke up her engagement and kept on working for one more year at the Barnard College in New York City.

In 1906, Harriet travelled to Paris and became an independent researcher working with Marie Curie at the Institute de Radium in Paris, France. Marie Curie invited Harriet to stay for one more year, but she decided to go to England for a faculty position at the University of Manchester.

In 1907, when Harriet returned to Canada, at the age of 31, she married a wealthy engineer of the Montreal Power and Water Company who was a former physics instructor at McGill University. After marriage, Harriet stopped working raising three children; two of whom tragically died in their teens. Harriet Brooks died in 1933 in Montreal at the age of 57 "of a blood disorder" - presumably leukemia caused by radiation exposure.

In Harriet Brooks obituary, New York Times described her as "Discoverer of the Recoil of a Radioactive Atom". Rutherford also wrote a highly laudatory obituary in the Journal of Nature 131 (3320) page 865. He said, Harriet's contributions to physics became recognized as fundamental work in nuclear science. She was the first person to show that radioactive substance emitted from thorium was a gas with molecular weight of 40-100, a discovery crucial to the determination of transmutation of elements in radioactivity decay.

In 2002, 69 years after Harriet Brook death, she was inducted to the Canadian Science and Engineering Hall of Fame. Also, at the Nuclear Research Laboratory at Chalk River laboratories, a building was named after her.

Harriet Brooks legacy is that she was the first Canadian female nuclear physicist. She is most famous for her radioactivity research. She discovered atomic recoil, and transmutation of elements in radioactive decay. Ernest Rutherford, who guided Harriet graduate work, regarded her as comparable to Marie Curie in the caliber of her aptitude. She was among the first persons to discover radon and to determine its atomic mass. [29, 30, 31, 32, 33, 34]

3.2 Edith Quimby (1891-1982) - First Woman Medical Physicist in the USA (AAPM - established in 1958)

Edith Quimby was born in Rockford, Illinois. She studied at the University of California and was awarded MSc degree in physics in 1916. She was appointed assistant physicist to Gioacchino Failla at the Memorial Hospital in New York City in 1919 - thus, making her the first woman to be appointed as a medical physicist in the AAPM. Edith developed a widely employed dosimetry system for single plane implants with radium and radon seeds. This is widely known as the Quimby System, and a dosimetry methodology for internal radionuclides.

Quimby has published the first comprehensive physics textbook for radiologists “*Physical Foundations of Radiology*” (co-authored with Otto Glasser, Lauriston Taylor, and James Weatherwax). She has also published “*Radioactive Isotopes in Medicine and Biology: Basic Physics and Instrumentation*” (co-authored with Sergei Feitelberg). In 1936, she became one of the first physics examiners for the American Board of Radiology (ABR) and served as President of the American Radium Society in 1954.

Prof Edith Quimby is known as founder of Nuclear Medicine. She developed diagnostic and therapeutic applications of X-rays. When she moved to New York City and worked at Memorial Hospital Cancer Institute, she studied energy emitted by potential materials for nuclear medicine as well as the amount of radiation absorbed by the body from different sources. In 1941 she was appointed to the faculty of Cornell University Medical College in New York as an assistant professor of radiology. The following year, she became an associate professor of radiation physics at the College of Physicians and Surgeons in Columbia University in New York City. In 1954, she was promoted to full professor and retired in 1960.

Prof Quimby has received many awards including the Janeway Medal from the American Radium Society (1940), the Radiological Society of North America (RSNA) Gold Medal (1941), and the Gold Medal of the American College of Radiology (ACMP) in 1963. Dr Quimby was also awarded honorary doctorate degrees by Whitman College in Walla Walla, Washington (1940) and Rutgers University New Jersey (1956). In 1963, Prof Quimby received Gold Medal from the American College of Radiology (ACR). She was one of the first few members of the AAPM Organization. In 1977 Prof Quimby received the AAPM prestigious Gold Medal Award named after William Coolidge. Later in 1966, AAPM established a Lifetime Achievement Award in honor of Prof Edith Quimby.

Prof Quimby has been recognized for her scientific work throughout her career. She became member of several scientific societies. In 1940, she was the first woman to receive the Janeway Medal from American Radium Society for her work in Specification of Doses in Radium Therapy. Prof Quimby is known as “Mother of Nuclear Medicine”. She was elected as the first female president of the American Radium Society (1954). One of Prof Quimby research article, released in 1962, was “Late Radiation Effects in Roentgen Therapy for Hyperthyroidism” where she suggested ceasing the use of all Roentgen X-rays in radiation therapy until its long-term treatment effects is better understood. [35, 36, 37].

3.3 Ann Wright (1922-2016) – First Woman Medical Physicist President of AAPM in the USA

Ann E. Wright grandparents moved to NY City from Ireland. She was born in New York City in 1922. In high school, even though Ann Wright was outstanding in mathematics, but the physics teacher would not allow her to take physics courses – “girls could not do physics”. However, Ann’s math teacher eventually persuaded the physics teacher to allow Ann to sit into his class. But she was not allowed to do any practical physics lab classes involving electricity – “which was too dangerous for girls”. Ultimately, however, the physics teacher was softened and gave “D” to Ann.

Upon graduation from high school, Ann received a scholarship to study physics at the University of Houston, in Texas. Unfortunately, Ann had to work for the Shell Oil Company for financial reasons. Initially she did clerical work but soon was promoted to work as an accountant. Recognizing her abilities in math, Shell Oil Company sent her to study computer programming at IBM (International Business Machine). This changed Ann’s professional trajectory. However, she could not be promoted at IBM without a college degree. She returned to Shell Oil Company to pursue a BSc degree in Business at the University of Houston. While there, she took a physics course and did so well that her teacher persuaded her to change her major to physics even though she was just two courses short of graduating in Business.

Later, Ann was encouraged by her physics teacher to respond to a job opening at the MD Anderson in Texas to get some additional income. She was interviewed by Prof Bob Shalek who recognized her unique ability in computer programming. He offered Ann a part-time job while completing her BSc degree. Ann helped Marilyn Stovall at MD Anderson to develop a database for brachytherapy data collection analysis and treatment planning calculations.

Eventually in 1951, at age 39, Ann completed her BSc in physics at MD Anderson. Under Prof Bob Shalek leadership Ann received an NCI (National Cancer Institute) scholarship to ultimately complete an MSc and PhD in medical physics. Subsequently, Ann began her career as a medical physicist in Houston and Galveston in Texas.

Dr Ann Wright served as AAPM Treasure (1974-1976). She also served as Chair of the Board of the Chancellors of the ACMP (American College of Medical Physics) in 1984. She received Marvin Williams Award in 1991. She served as AAPM Representative to the AIP (American Institute of Physics) Governing Board Executive Committee. Dr Ann Wright became AAPM President in 1982.

Prof Ann Wright will be remembered, not only as a great leader of the medical physics profession, but as a great role model for young women and men who intend to pursue medical physics profession. The medical physics profession in USA is where it is today in large part due to Prof Ann Wright efforts. Her influence in AAPM will be felt for many years to come. [38, 39].

3.4 Sylvia Olga Fedoruk (1927-2012) - First Woman President of Medical Physics in Canada (Division of Medical and Biological Physics (DMBP): Established in 1946)

Sylvia Fedoruk was one of the pioneers in applying the principles and experimental techniques of physics to improve patient care in Canada. Born in Canora, Saskatchewan, to immigrant Ukrainian parents. She grew up in rural Saskatchewan at Wroxton. She moved to Windsor, Ontario during WWII and there her English teacher encouraged her to pursue a career in science.

After finishing high school, Sylvia completed her Bachelor (1949) and Master (1951) degrees in physics from the University of Saskatchewan. As a campus athlete in the 1940s, Sylvia played basketball, hockey, volleyball, track and field and golf. She won a western Canadian softball championship with the Saskatoon Ramblers in 1955, and Canadian women's curling titles in 1960 and 1961.

Sylvia was academically outstanding and received many scholarships and awards for her excellence. Sylvia was a pioneer in leading-edge cancer research, primarily in the field of nuclear medicine. Sylvia Fedoruk was recognized worldwide for her work in the scientific community. Her area of expertise was medical physics, and she was the only woman in Canada who was researching medical physics in the 1950s. Her biggest activity was her involvement in the development of the Cobalt 60 units for cancer treatment. Sylvia worked on a dosimeter that allowed for greater control over radiation dosage.

Sylvia began her career in 1951 as part of the staff of the University of Saskatchewan. This was where she co-developed the Cobalt 60 Therapy Unit. In 1956 she became an assistant professor at the university and 17 years later in 1973 she became a full professor. She was the first woman elected Chancellor of the University of Saskatchewan in 1986 and she held that post for 4 years. Throughout her life she worked for several different organizations and boards, including the Saskatchewan Cancer Foundation, the Saskatchewan Commission on Direction in Health Care, the Atomic Energy Control Board of Canada, and the International Atomic Energy Agency. She was also the first female trustee of the Society of Nuclear Medicine. In 1988 she was sworn as the first woman Lieutenant Governor of Saskatchewan and held the office until 1994.

Sylvia scientific achievements gave her worldwide recognition and her work will continue to be an inspiration to many scientists. In addition to her tremendous scientific accomplishments, she defied odds and became the first woman in many activities in Canada.

Sylvia Fedoruk's scientific career helped laying the foundations of use for today's essential diagnostic and treatment technologies including CT (Computed Tomography) and PET (Positron Emission Tomography) scanners. Sylvia calculation tables for radiation treatment became the world standard for depth and dose measurement and remain so to this day. Additionally, as a pioneering woman in the fields of physics and state service, Sylvia Fedoruk's life continues to inspire women to break glass ceilings and all people to strive for excellence.

A pioneering woman of science—one of the few Canadian female medical physics researchers in the 1950s—Sylvia also went on to serve as the university's first female chancellor (1986) and the province's first female lieutenant-governor (1988). At a time when there were few highly placed female leaders in academe, Sylvia excelled as a competitive student-athlete. Her remarkable career touched on many of the scientific, political, and social challenges of her time, including nuclear energy issues, women's equality, and gay rights.

As a graduate student of medical physicist of Dr Harold Johns, Sylvia established the world standard for radiation depth-dose measurements to treat tumors deep inside the body. The cobalt-60 therapy unit was a groundbreaking advance in cancer treatment innovation that positioned University of Saskatchewan to become a leader in areas of nuclear medicine and biomedical imaging that is today.

Sylvia was a strong supporter of women in science. She was the first woman to join the Atomic Energy Control Board of Canada, an advisor to the Federal government on radioisotopes, and a consultant with the International Atomic Energy Agency throughout the 1960s. Due to her national reputation, Sylvia was included in Queen Elizabeth II visit's list in 1977.

In 1986, Sylvia was named the first female Chancellor of the University of Saskatchewan. She was made an Officer of the Order of Canada in 1987. Two years later she was appointed the first Lieutenant Governor of the province. In 2009, Sylvia Fedoruk was inducted to the Canadian Medical Hall of Fame in Montreal, Quebec. In 2011, the Sylvia Fedoruk Canadian Center for Nuclear Innovation was opened. The Center supports nuclear research and manages the Saskatchewan Centre for Cyclotron Sciences.

Dr Sylvia Fedoruk received many Awards & Honors during her 35 years carrier including but not limited to: Queen's Silver Jubilee Medal (1977), Officer of the Order of Canada (1986), Saskatchewan Order of Merit (1986), Honorary DSc, University of Windsor (1987), Honorary Degree, University of Regina (1991), Canada 125th Commemorative Medal (1992), Honorary LLD, University of Saskatchewan (2006). [40, 41, 42]

3.5 Margaret Young (1922-2012): Pioneer Scientist in Canada

Margaret Jane Carr was born in Ealing, London, England in 1922. Following primary school, she was educated at Haberdasher's Aske's School which was evacuated to Dorchester during WWII. She had her physics education at prestigious Royal Holloway College in London, London University England. She received her BSc in 1943 and her MSc in 1949.

In 1942, at the age of 20, while Margaret was working for her physics degree, she was invited to become the youngest founding member of the Hospital Physics Association (HPA) in UK. She continued to work as a lecturer in physics at the Royal Free Hospital (1943 – 1949). While working for her physics degree, Margaret moved to Canada and worked as a physicist at the MRC (Medical Research Council) Radiobiological Research Unit at the Atomic Energy Research establishment (1941 – 1951).

In 1951 Margaret married Dr Young and accompanied him to Ottawa, Canada. Margaret worked as a physicist at the Ottawa Civic Hospital. From 1952 to 1955 Margaret and her husband, Dr Young, returned to London, UK where Margaret worked at the Charing Cross Hospital, a teaching hospital (established in 1818) in London, UK.

In 1955, Margaret and her husband returned to Canada, and took residency in Vancouver. From 1955 to 1985, Mrs Young was employed as medical physicist by the Cancer Control Institute of British Columbia (now known as the B. C. Cancer Agency: BCCA). Working half time, she did extensive teaching for the nurses (who have now been replaced by therapists for treatment delivery and radiographers). She wrote a textbook titled "Radiological Physics" which is still in use at BCCA today. The first, second, and third editions of this book were published by H. K. Lewis & CO. in London, UK in 1957, 1967, and 1983 respectively.

In addition to the textbook, perhaps Mrs Young is best known for her contribution to medical physics and the work she did on Radium Tables. Mrs Young performed the calculations for converting the in-air dosimetric data to tissue dosimetric data. She worked with a primitive computer in the 1960s to accomplish this work. She was also involved in intra-peritoneal treatment for ovarian carcinoma using ³²P and had some involvement with the

negative pi meson medical facility at TRIUMF which is Canada's national particle accelerator center and is considered as Canada's premier physics laboratory and world's leading subatomic physics research center.

By 2009, Mrs Young received many awards and honors including Gold Medal from the College of Medical Physics (COMP). In 1978, at the annual meeting of the Canadian Association of Physicists (Division of Medical and Biomedical Physics) in London, Ontario, Margaret Young was acknowledged as one of the six founding members of the Canadian College of Medical Physics. The Youngs remained in Vancouver, where Margaret Young passed away in 2012. [43]

3.6 Chien-Shiung Wu (1912-1997) – An Eminent Early Physicist in the USA

Chien-Shiung was born in Liuhe, a small town near Shanghai, China. When she was growing up in China, there was little opportunity to have a formal education. Her father (accompanied by his daughter) went door to door to recruit students from poor and rich families alike. The goal was to eradicate illiteracy and discrimination against women by giving them good education.

Chien-Shiung was encouraged by her father to pursue an education beyond her hometown. In 1923 at age 11, Chien-Shiung applied to join teacher training program at the Soochow Girl's High School that was a prestigious and highly competitive program in China. In 1929, Chien-Shiung graduated from High School with high grade in her class. From 1930 to 1934, Chien-Shiung studied physics at the National Central University in Nanjing, China, a very competitive school. In 1936, Chien-Shiung went to United States for completion of her education.

Chien-Shiung enrolled at the University of Michigan to pursue her PhD degree in physics. After a week, she changed her mind when she visited the University of Berkely (UC Berkley) in California where she found it to be more liberal than Michigan. When Chien-Shiung physics advisor (Luke Chia-Liu Yuan) received a grant to work at the California Institute of Technology (Caltech) in Pasadena, California, she stayed at the UC Berkley until she graduated in 1940.

After graduation, Chien-Shiung worked with Enrico Fermi, who had made the first US nuclear reactor in Chicago, Illinois. Later Chien-Shiung was invited by Robert Oppenheimer, a theoretical physicist known as "father of the atomic bomb" to give a talk about her latest nuclear fission research at the UC Berkely where she had performed parity conservation experiments in beta decay. By this time Chien-Shiung was known as the "Chinese Marie Curie".

In 1942, Chien-Shiung married Luke and decided to leave UC Berkely where women were not offered teaching positions. Unfortunately, at that time such practices were often seen in the top-20 Universities in USA. Later the role of women was recognized at the Ivy Schools in Eastern USA. Chien-Shiung eventually taught at Smith College, a private women's liberal arts college in Northampton, Massachusetts.

Chien-Shiung and Luke had started their family and stayed in US where it was especially difficulty to return to China during the Japan-China war that erupted in 1937. Chien-Shiung had lost all her contacts with her family in China. When Japan was defeated in WWII, Chien-Shiung went to China and sadly found out that her parents and brother had died.

In 1950s, particle accelerators became popular and new subatomic particles were discovered. The physicists Lee and Yang at Columbia University and Princeton respectively had proposed the idea of parity conservation applied to electromagnetic and strong interactions that did not apply to weak interactions based on the discovery of K-meson particle. Therefore, they needed help from Chien-Shiung to prove their theory. The result of her experiment eventually established parity conservation as a fundamental law of physics.

Even though Chien-Shiung was not considered for Nobel Prize when Lee and Yang received it in physics (1957), Chien-Shiung received many awards and honors until she retired in 1980. She was named "Scientist of the Year" in 1975 and became the first female president of the American Physics Society. In 1978 she received the first Wolf Prize in Physics. She died in 1997 in New York City and her ashes were taken to China and was buried in the courtyard of the Mingde School near Shanghai, China. [44, 45, 46, 47, 48].

3.7 Ellen Elizabeth Grein, El-Khatib, Wilcox (1950): First Woman President of Canadian Organization of Medical Physicists (COMP, Established 1989):

Ellen Elizabeth Grein was born in Heppenheim, West Germany in 1950. From (1973 -1975), Ellen worked as a research assistant under the leadership of Dr. Willi Stahlhofen at the Institute of Radiation and Environmental Research in Frankfurt, Germany. She then moved to Canada and became aware of the field of medical physics. From 1976 to 1979 Ellen worked as electron microscopist in Dr Marc Cantin Laboratory in the Pathology Department of the University of Montreal.

In 1971, Ellen Grein received her BSc in physics from Loyola College, Montreal, Quebec, Canada. She then received her MSc in physics from Concordia University in Montreal, (1980). She was Dr Jerry Battisa first PhD student at the University of Alberta. She completed her PhD in medical physics at University of Alberta, Edmonton, Alberta, Canada (1984). Dr Ellen El-Khatib's first position in clinical medical physics was with Dr Ervin Podgorsak at McGill University in Montreal where she was employed by the Montreal General Hospital as a clinical physicist in 1984.

From 1985 to 1987 Dr Ellen El-Khatib was appointed to an academic position as assistant professor at McGill University in Montreal. From 1987 to 1988, she worked as medical physicists at the King Faisal Specialist Hospital and Research Center in Riyadh, Saudi Arabia. She then returned to Canada and took a position as senior medical physicist at the Cross Cancer Institute in Edmonton, Alberta. At the same time, she had academic appointment as adjunct professor in Physics Department at the University of Alberta.

In 1991, Dr Ellen El-Khatib took a position as senior medical physicist at the British Columbia Cancer Agency (BCCA) in Vancouver, Canada. In 1992, she was appointed Department Head of Medical Physics and Professional Practice Leader for Medical Physics at BCCA. Under Ellen's leadership medical physics at the BCCA grew to become the largest radiation medical physics group in Canada. Since 1991, the number of physicists increased from 9 at two centers to 35 in four centers in 2003. She recruited more than 30 physicists and oversaw the development of essentially three entirely new cancer centers, and a major reconstruction of the Vancouver Cancer Center (VCC) radiation facility. During this time Ellen also oversaw the expansion of the Screening Mammography Program of BC, the establishment of proton therapy at TRIUMF particle accelerator center in Vancouver, BC. She also initiated stereotactic radiosurgery and prostate brachytherapy as provincial programs at VCC.

In addition to facility and program development, Dr Ellen El-Khatib built an academic program in graduate medical physics at the University of British Columbia, from which five PhD students and two MSc students were graduated when she left in 2003. This program obtained AAPM CAMPER (Commission on Accreditation of Medical Physics Educational Programs Accreditation) in 2003.

Later Dr Ellen El-Khatib Wilcox moved to the US and took a position as Chief Medical Physicist at Saint Francis Hospital and Medical Center, in Hartford, Connecticut. Although no longer practicing in academic environment Ellen has remained active in research, clinical development, and mentoring new graduate medical physicists at the start of their careers.

Dr Ellen Wilcox has published numerous articles in national and international journals. In 1991, Ellen received AAPM Travel Award to present papers at the World Congress of Medical Physics in Kyoto, Japan. From 2000-2004, Ellen has served as Associate Editor, Medical Physics Journal. She continued as Reviewer and Guest Associate Editor for Medical Physics Journal. Ellen has been active in AAPM committees and Task Groups: Education and Training of Medical Physicists (1998), Awards Selection Subcommittee, Task Group 1: Revision of Report 44: Academic Programs for MSc Degree in Medical Physics, Task Group 69: Radiographic Film Dosimetry (2001).

Dr Ellen Wilcox became certified in 1985 from the Canadian College of Physicists in Medicine. In 1987, Ellen became Fellow of the Canadian College of Physicists in Medicine (FCCPM). In 2003 Ellen was recognized as Fellow of the American Association of Physicists in Medicine (FAAPM). [49, 50,51].

3.8 Azam Niroomand-Rad (1947) – First Woman President of the IOMP

Azam Niroomand-Rad was born in Tehran, Iran. She studied math and physics in middle school and high school. Recognizing Azam abilities in math and physics, she was encouraged by her math/physics teacher to study physics

that was not an ordinary choice for girls in Iran. Being inspired by Maria Skłodowska-Curie personal and professional challenges in Poland and France, Azam applied and won a Fulbright Scholarship to go to USA for her college education in 1966.

Azam excelled in math and physics. She supported herself by receiving scholarships and awards every year. At college Azam studied mathematics for first two years and physics for the last two years. In 1970 Azam received her Bachelor of Science (BSc) with a major in math a minor in physics from the State University of New York, Albany, New York. She, graduating with honors; Summa Cum Laude and Phi Beta Kappa. Azam then went to Michigan State University (MSU) in E. Lansing Michigan and completed her Master of Science (MSc) in physics (1971). When meeting her future husband, Dr Hossein Hamedani, she returned to Iran and taught physics at the Department of Physics at the Arya Mehr University of Technology in Tehran from (1971-1975). Azam and her family then returned to USA and she completed her PhD in Atomic and Molecular Physics at the MSU in 1978.

From 1978 to 1980 Azam and her family returned to Iran and taught physics at the Department of Physics at the Arya Mehr University of Technology in Tehran. Initially, she was excited looking for establishment of a “Government of the people, for the people and by the people”. However, when Ayatollah Khomeini went to Iran (1978), an authoritarian monarchy (Mohammad Reza Shah) was replaced with another authoritarian Islamic Republic of Iran. The Arya Mehr University of Technology was seized by the Islamic fundamentalist and name of the Arya Mehr University of Technology was changed to Sharif University of Technology. From 1978 to 1987, the academic universities in Iran were closed for so-called “cultural revolution”.

In 1980 Dr. Azam Niroomand-Rad and her family returned to USA. She then applied for National Institute of Health (NIH) Fellowship that enabled her to join the Department of Medical Physics at the University of Wisconsin in Madison, Wisconsin. Azam was the last Postdoc of Prof John Cameron. Azam worked under supervision of late Prof John Cameron and late Prof Herb Attix. She specialized in therapeutic medical physics. A couple years later, Azam became a member of AAPM and IOMP. Azam is certified by the American College of Radiology (ACR) in therapeutic medical physics (1988) and by the American Board of Medical Physics (ABMP) in Radiation Oncology Physics (1990).

From (1983-1988) Dr Niroomand-Rad worked as Assistant and Associate Professor at the Medical College of Wisconsin in Milwaukee, Wisconsin. In 1988, she moved to Washington D.C. and worked as Professor and Clinical Director of Medical Physics Section at the Department of Radiation Medicine at Georgetown University Medical School until her retirement in 2010. After retirement she returned to Madison, Wisconsin where she is continuing her research as an Honorary Professor at the Department of Medical Physics, University of Wisconsin in Madison, Wisconsin.

Prof Azam Niroomand-Rad has served on many AAPM committees and Task Groups including Chair of Radiation Therapy Working Group (1985), Organizer of Scientific Meetings at North Central and Midwest Chapters of AAPM, member of the AAPM Board of Directors (1986-1989) and (1997-2000), Finance Committee (1988-1991), International Affairs Committee (1988-1991), Ethics Committee (1988-1991), Chair of Task Group 1 to develop courses for developing countries (1990-1991), Chair of Developing Countries Committee (1989-1991), member of Radiation Protection Committee (1989-1996), Member of Task Group No. 46, Accelerator Beam Data (1989-2000), member of Radiation Therapy Committee (1992-1994), member of Local Arrangement Committee (1992-1993), Chair of Task Group 55 1993-1997 for radiochromic dosimetry, Chair of Education Committee of Mid-Atlantic Chapter (1994-2000), President of Mid-Atlantic Chapter (1996-1997), member of Awards and Honors Committee (1996-2001), Appointed Delegate to IOMP (1996-2000), ABMP Oral Examiner (1997), ABR Oral Examiner (1996, 1998, 2000, 2002, 2004, 2006), Chair Presidential Ad Hoc Committee, Women issues (1996-1997), Chair Task Group 8 Women in AAPM (1997-1999), Organizer of Symposium on Women in AAPM (1998), Course Director, Nashville, TN (1999), member of Long-Term Planning Committee (2000-2004), member of Science Council (2000-2004), Associate Editor of Medical Physics Journal (2001-2005), member of Education Council (2000-2006), member of History Committee (2007-2013), and Chair of Task Group 235 an update to radiochromic dosimetry (2012-2020).

Prof Azam Niroomand-Rad has served on many IOMP committees including member of Education and Training Committee (1991-1997), working with International Labor Organization (ILO) (1991- 2008) to establish Medical Physics profession in the listing of the International Standard Classification of Occupations (ISCO-2008), Chair of Education and Training Committee (1997-2000), Co-Chair of Advisory Committee for World Congress Planning Committee, in Chicago (1996-2000), Elected Vice President (2000-2003), President (2003-2006), Past

President (2006-2009), Awards and Honors Committee (1998-2000), member of IAEA (International Atomic Energy Agency) Scientific Committee (2001-2002), Organized First US-Cuba International Conference in Medical Physics in Havana, Cuba (2000-2002), an IAEA Expert, Radiation Therapy Physics, Jordan (2003), member of Program Committee of Poland Society of Medical Physics (2005), Chair History Subcommittee (2008-2019), co-organized Middle East First International Conference of Medical Physics in Shiraz, Iran (2011), and International Union for Physical and Engineering Sciences in Medicine (IUPESM) International Advisory Committee, World Congress, Toronto, Canada (2015).

Prof Azam Niroomand-Rad was Editor of IOMP Medical Physics World (MPW) Bulletin (1994-2000), Managing Editor and member of Electronic MPW (1996-2000), Azam was elected as IOMP first female Vice President in Chicago and (thus far the only) female medical physicists to serve as President (2003-2006) and Past President (2006-2009). She worked with ILO (International Labor Organization) for recognition and inclusion of Medical Physicists in the International Standard Classification of Occupations (ISCO-2008) that helped to open many doors to women medical physicists (WMPs) in health professional and health services.

Prof. Azam Niroomand-Rad is founder of the AAPM / IOMP International Scientific Exchange Programs (ISEP) Courses and Workshops in 1989. She has served as Chair of ISEP (1989-2006) and has helped to expand and advance medical physics organizations and associations in several developing countries including (but not limited to) Tehran, Iran (1991), Islamabad, Pakistan (1992), Baghdad, Iraq (2010), Rabat, Morocco (1996), Cairo, Egypt (1998), Moscow, Russia (1997), Istanbul, Turkey (1995), Bangkok, Thailand (2000), Dhaka, Bangladesh (2001), Riyadh, Saudi Arabia (2002), Manila, Philippines (2005), Yaoundé, Cameroon (2005), Nairobi, Kenya (2005), Chengdu, China (2004), Program Committee Nuremberg, Germany (2005), and Manama, Bahrain (2007).

Dr Azam Niroomand-Rad was as active member of electronic encyclopedia e-Encyclopedia of Medical Physics and Multilingual Dictionary of Terms, (EMITEL), and has coordinated scientific dictionary for Persian translation of EMITEL. She has published many articles, several Books, Book Chapters, and article describing Role and Responsibilities of Medical Physicists in Radiological Protection of Patients for IAEA.

Dr Azam Niroomand-Rad has been thesis advisor and co-advisor of three PhD students and eight MS students. She was Co-Inventor of couple patents with one patent registered at the US patent Office in December 2008. She has received many honors and awards including Honorary Doctor of Science Degree (DSc.) from Regent of the University of the State of NY (2001), Teacher of the Year Award, from Association of Residents in Radiation Oncology (2001), AAPM Life-Time Achievement in Medical Physics (Quimby Award) (2006), IOMP Marie Skłodowska Curie Award (2009). She is Fellow of AAPM (1997), Fellow of IOMP (2013) and Fellow of IUPESM (International Union for Physical and Engineering Sciences in Medicine (2022). Azam scientific and professional video interviews as conducted by late Prof. John Cameron (2004) and as conducted by Prof. Colin Orton (2021) as well as her biography are available at the AAPM History & Heritage video archives [52,53, 54, 55].

4. Pioneer Women Medical Physicists in the IOMP Regional Organization in Europe (EFOMP Region - Established in 1980)

In 2021 Medical Physics International (MPI) Journal published series of articles focused on the development of Medical Physics in EFOMP Regions [56, 57]. In addition, several MPI were published describing EMITEL/ EMERALD programs [58, 59, 73] as well as ICTP programs in Trieste, Italy [62, 73].

As per a survey in 2014 [79] the median value of female medical physicists in Europe is 47% of the professional workforce. As per data from 2015 [80] all medical physicists in the EFOMP Region were c.8400.

4.1 Edith Anne Stoney (1869-1938): First Woman Medical Physicist in Europe

Dr Edith Anne Stoney was born in 1869 in Dublin, Ireland. Her father was a well-known physicist. Edith graduated from Newnham College, Cambridge, Britain, but was not awarded a degree in 1893 as at that time women were excluded from graduation. However, later she was awarded BA and MA degrees from the Trinity College in Dublin, after they accepted women in 1904.

In 1874 London School of Medicine for Women was established that was the first medical school for women in Britain. In 1899 Edith Stoney started to work in this School as physics lecturer, thus becoming the first woman in the world to be employed in the field of medical physics. At that time medical students in Britain were taught by top physicists (such as J. J. Thompson in Cambridge). In 1901, the British Royal Free Hospital employed Edith and her sister Florence. The two sisters were in charge of selecting, purchasing, and installing x-ray equipment. During WWI Edith Stoney was trained to operate x-ray units.

During WWI, Edith Stoney established stereoscopy to localize bullets and shrapnel and introduced the use of X-rays in the diagnosis of gas gangrene. After the war Edith Stoney took a post as lecturer in physics at the King's College for Women. In 1936, Edith and Florence established Stoney Studentship in the British Federation for University of Women (BFUW) for research in biological, geological, meteorological, and radiological sciences. The Stoney studentship is now being administered by the Newnham College in Cambridge and supports clinical medical students going abroad for their elective period. Edith Stoney died in 1938 at age 69. [61]

4.2 Andrée Dutreix – Pioneer Woman French Medical Physicist

Andrée Dutreix studied math, physics and electronics at Sorbonne in Paris. She devoted her attention to the physical problems in medicine. She worked at the Institute of Gustave-Roussy, Villejuive, France. She developed standards for quality assurance in brachytherapy and tele-radiotherapy.

In 1949, nuclear medicine was a booming field. In 1950, Frédéric Joliot, then France's High Commissioner for Atomic Energy, decided to acquire a Betatron particle accelerator for nuclear experiments. To share the cost of the accelerator, he set up a team at the Institute Gustave Roussy (IGR). By 1953, the Betatron was to treat patients in the morning and to run physics experiments in the afternoon. Physicists did not want to work in a medical environment, for fear of not getting opportunities to do any scientific work. Andrée Dutreix took on the challenge and joined the team.

Andrée Dutreix was good in math and drawings. She calculated treatment dose distributions for Betatron. She made manual calculations prior to use of basic computers. Andrée Dutreix wrote Fortran code and calculated brachytherapy-treatment doses on an IBM computer.

Prof Andrée Dutreix made great contributions to the field of radiotherapy. Among her achievements, she improved the sparing of healthy tissue, changed the practice from kilovolt to megavolt treatments. She worked to obtain recognition for the medical physicists who worked with her. She created the first medical physics diploma in France in 1970. She managed the radiation Hospital in Villejuif, France for many years and later became a teacher at Louvain University.

Prof Andrée Dutreix became a corresponding member of the German Roentgen Society in 1979 and was awarded the Roentgen Plaque in 1986. She also received IOMP Maria Skłodowska-Curie Award at World Congress 2003 in Sydney, Australia. On July 2009, Prof Andrée Dutreix was interviewed by Prof Azam Niroomand-Rad in her home in Paris on behalf of IOMP. The video interview is available at IOMP History Committee Archive. [63, 64, 65]

4.3 Roberta Breschi: First Woman Medical Physicist in Italy

Roberta Breschi was born in Prato, Italy. In 1961 she defended her doctorate in health physics at the Rome University "La Sapienza". Dr Roberta Breschi started her career as medical physicist (Radiotherapy) in the San Camillo Hospital, Rome, Italy.

In 1971 Dr Roberta Breschi became Director of the "Autonomous Health Physics Service" of the Pio Istituto di Santo Spirito in Rome. Dr Roberta Breschi had a wide profile of sub-specialties in medical physics. She was member of the Ministry of Health Commissions and Expert in medical physics and Qualified Expert Grade II for radiation protection.

Dr. Roberta Breschi also lectured medical physics for health professions at Lazio Regional and University Schools in Rome. She was member of the Board of Arbitrators of AIFM and AIRP (the Italian Associations in Medical Physics and in Radiation Protection). After her retirement, Roberta Breschi loved to deepen her culture on "Medical Physics", considering it a "Science for life" to evaluate the risk-benefit relationship in research, technological development, and healthcare.

4.4 Maria Stefanova (1922-1985): First Woman Medical Physicist in Bulgaria

Maria Grozdanova-Stefanova was born in Bulgaria in 1922. She was the first woman medical physicist in the country who in 1946 graduated in physics from Sofia University, in Bulgaria. She was then employed as lecturer in medical physics in the new Department of Medical Physics at the Medical Faculty of Plovdiv University, Bulgaria that was established in 1945. As part of her research, Maria made some of the first environmental radiation measurements in the country.

Dr. Maria Stefanova worked at the Medical University Plovdiv until her retirement. She authored several textbooks on medical physics in Bulgaria. Her daughter, Dr Vassilka Tabakova, also became a medical physicist and in 2020 published the first book on e-Learning in Medical Physics. She also took active part in the EMITEL Encyclopedia of Medical Physics. She worked along with her husband Slavik Tabakov in developing e-learning international materials EMERALD and EMIT - projects that received the EU Leonardo Da Vinci Award. [59, 60]

4.5 Barbara Gwiazdowska (1927-2014): First Woman Medical Physicist in Poland

Barbara Gwiazdowska was born in Warsaw, Poland in 1927. Prof. Barbara Gwiazdowska was the first woman working as medical physicist in Poland. She studied at the Faculty of Electrical Engineering of the Lodz University of Technology in Lodz, Poland. She then moved to Warsaw and studied at the Department of Physics of the Institute of Oncology Warsaw University of Technology. Under leadership of the department head, Dr Cezary Pawłowski, she was able to receive her PhD in the field of medical electrical engineering.

In 1952, Dr Barbara Gwiazdowska defended her diploma thesis and started working at the Department of Physics of The Maria Skłodowska-Curie Institute — Oncology Center Radium Institute in Warsaw. The Radium Institute was established in 1932 with support of Marie Curie's sister, Dr Bronisława Dłuska who put great efforts for the establishment of the Radium Institute in Poland. From 1965, Prof Dr Barbara Gwiazdowska was active in establishing the Polish Society of Medical Physics in Poland.

Dr Barbara Gwiazdowska served as national consultant in the field of medical physics in Poland. In 1972 she became Head of the Department of Medical Physics and at the same time, she was active in creating the specialty of medical physics at the Faculty of Physics of the University of Warsaw. Her activities were successful and her first student defended thesis in 1974.

Under the supervision of Prof. Barbara Gwiazdowska, a professional measurement laboratory was established, which was transformed into the Laboratory of Secondary Dosimetric Standards and became integrated into the international network under the auspices of IAEA.

In 1985, Prof Barbara Gwiazdowska received the highest university degree, Dr. habil and in 1996 the title of professor. From 2004 she was the National Consultant for Medical Physics. For many years, she simultaneously worked at the Oncology Center in Warsaw.

In 2013, Prof Barbara Gwiazdowska invited Professor Azam Niroomand-Rad to Krakow, Poland for the inauguration of First International Day of Medical Physics (IDMP) that had been established on 7 November – the birthday of Maria Skłodowska-Curie. As IOMP Past President, Azam made several presentations and reviewed Marie Skłodowska-Curie (1867-1934): A Scientist Ahead of her Time – Historical Overview, Tribute and her Contributions to Physics, Medicine, and Cancer Treatment. Moreover, Prof Barbara Gwiazdowska invited Azam to Warsaw to visit Marie Curie birthplace and Museum. [57]

4.6 Inger-Lena Lamm: Swedish Medical Physicist, First Woman President of EFOMP

Inger-Lena Lamm was born in Sweden. She studied at the Lund University, Faculty of Engineering in Sweden. In 1965, she graduated with a Master of Science in Engineering, Engineering Physics. She was teacher and researcher at the department of mathematical physics (1964-1974). She received her PhD in “Theoretical studies of some equilibrium properties of stably deformed nuclei” in 1974.

In 1974 Dr Inger-Lena Lamm changed her studies from mathematical physics to radiation physics – to use physics to the benefit of diagnosis and treatment of patients – formally completing her MSc in Medical Physics in 1976.

Dr Inger-Lena Lamm worked as medical physicist at the Lund University Hospital and she was engaged in clinical radiotherapy, education, training, and research from 1974 until her official retirement in 2011. With her broad background in mathematics, she was the physicist selected to introduce CT in radiotherapy treatment planning in 1977. During the last 20 years Dr. Inger-Lena Lamm was responsible for all brachytherapy activities. She developed and introduced new high-dose-rate (HDR) and low-dose-rate (LDR) treatment techniques.

Dr Inger-Lena Lamm was very active in promoting the Medical Physics Profession, especially in the harmonization of education and training standards. She was instrumental in the development of Medical Physics as a regulated health care profession in Sweden (1999). She was President of the Swedish Hospital Physicists Association (SHPA) (1987-1997) and Vice President of the Swedish Association of Scientists (1994-2006).

Dr Inger-Lena Lamm was Chairman of the Education, Training and Professional (ETP) Committee of the EFOMP (1995-1999), and she became the first woman President of EFOMP (2000-2002). Among many other activities, Dr. Inger-Lena Lamm participated in the development of several Policy Statements and in the establishment of the European School of Medical Physics, ESMP in 1998.

Dr Inger-Lena Lamm was also a member of IUPESM and Administrative Council (the first woman elected at this position). She was in several advisory committees. She held Board member positions in national and international organizations. She participated in EU projects and in the organization of national and international conferences and workshops. She took active roles in e-learning International EU projects, European MEDical RADIation Learning Development (EMERALD) and European Medical Imaging Technology Training (EMIT). The team was awarded with the EU Leonardo Da Vinci Award in 2004.

Dr Inger-Lena Lamm continued as a member of the EMITEL Encyclopedia of Medical Physics team and coordinated the Swedish translation of the Scientific Dictionary of Medical Physics Terms (www.emitel2.eu). She was also involved in IAEA projects, among other things as lecturer in brachytherapy on regional training courses in Tunis in 1997 and in Cairo in 1999.

Since 1997 Dr Inger-Lena Lamm has been involved in radiation therapy standardization as an expert of International Electrotechnical Commission (IEC) subcommittee 62C, and she has been chairman of the Swedish mirror committee SEK TK62BC since 2005. She has received many awards including an Honorary member of EFOMP. She received the IEC Award in 1996. She became IUPESM Fellow (2022). [57, 58, 59, 73]

4.7 Anna Benini: First Woman (inaugural) Secretary- General of EFOMP

Anna Benini was born in Italy. She worked at the University of Parma and then moved to the IAEA. In 1988 Dr Anna Benini and Prof L. Bertocchi established the ICTP College on Medical Physics, dedicated to MP education for students from Low and Middle Income countries. ICTP - the Abdus Salam International Center for Theoretical Physics was founded in 1964 in Trieste, Italy by the Nobel Laureate Prof Abdus Salam. Dr Anna Benini was Co-Director of the College until she retired in 2018.

In 1980 Dr Anna Benini was elected the inaugural Secretary-General of EFOMP – the first woman at this position. Later she took active role in the EMERALD project developing MP e-learning materials. Dr Anna Benini was elected as inaugural member of Education and Training Committee (ETC) of IOMP (1985-89) and was member of IOMP Professional Relation Committee (PRC) during (1994-1997). She was awarded with the ICTP Outstanding Role Diploma. Currently Dr. Anna Benini is retired and lives in Denmark. [57, 58, 62, 73]

5. Pioneer Women Medical Physicists in the IOMP Regional Organization in Latin America (ALFIM Region – Established in 1984)

In 2018 and 2019 Medical Physics International (MPI) Journal published several articles focused on the development of Medical Physics in Latin America. [66, 67]

As per a survey in 2014 [79] the median value of female medical physicists in Latin America is 24% of the professional workforce. As per data from 2015 [80] all medical physicists in the ALFIM Region were c.800.

5.1 Esther Nunes Pereira: (1916-2003) Pioneer Woman Medical Physicist from Brazil

Esther Nunes Pereira was born in the Federal District, (today the city of Rio de Janeiro), Brazil in 1916. She received her Bachelor of Science Degree in physics and mathematics from the Faculty of Philosophy at the University of Brazil In 1944. She was encouraged and influenced by Dr Osolando Machado, radiotherapist, to become interested in ionizing radiation.

In 1954, Esther was hired by the National Cancer Institute (INCA) in Rio de Janeiro for activities related to physics as applied to medicine in the sections of Roentgentherapy, Curietherapy and Radioisotopes at INCA. Esther took courses at the National Institute of Technology on Electric and Electronic Measurements (1952-1954), Radioisotope Methodology and Radiological Dosimetry at the University of San Paulo (USP).

From 1953 to 1958 Esther worked at the Nuclear Dosimetry and Instrumentation at CNEN in Brazil. On April 1960, with a scholarship from IAEA, Esther went to the Christie Hospital and Holt Radium Institute, in Manchester, UK, where she interned for one year until May 1961 under the supervision of Dr Meredith. She also took a course on Radioisotopes at the Isotope School in Wantage, UK.

From 1972 to 1973 Dr Esther Nunes Pereira assumed the leadership of the Sector of Agreements, Covenants and Autarchy of the National Division of Cancer. She became the Head of the Radiation Physics Sector at INCA, which at that time belonged to the National Cancer Division. After a lifetime dedication to the physics of ionizing radiation at INCA, she retired in 1986. She passed away in 2003. [67]

5.2 Simone Kodlulovich Renha: Eminent Woman Medical Physicist from Brazil, twice President of ALFIM (2010-2013) and (2013-2016)

Simone Kodlulovich Renha was born in Brazil. She obtained her PhD in Nuclear Technology with specialization in medical physics at Instituto de Pesquisas Energéticas e Nucleares in Brazil.

Since 1999 Simone Kodlulovich Renha worked as a researcher at the National Commission of Nuclear Energy (CNEN). For more than 10 years she was Head of Diagnostic Radiology Division of the “*Instituto de Radioproteção e Dosimetria*” (IRD/CNEN).

Since 2001 Dr Simone Kodlulovich Renha became a professor of the postgraduate program of IRD/CNEN where she supervised students' research mainly in diagnostic radiology and in radiation protection and safety in medical applications of ionizing radiation. Later she served as an IAEA expert and at present she serves as Coordinator of the IAEA project “Enhancing Capacity Building of Medical Physicists to Improve quality and safety in medical practices” for Latin America

From 2010 to 2013 Dr Simone Kodlulovich Renha served as President of “*Asociación Latinoamericana de Física Médica (ALFIM)*”. She was re-elected for the period (2013-2016) and of the *Radioprotection Federation of Latin America and the Caribbean* for the period (2018-2021). The first woman ALFIM President was the medical physicist from Venezuela Dr Lila Carrizales (1998-2001).

In IOMP, Dr Simone Kodlulovich Renha was a member of the Education and Training Committee and Chair of the Honors and Awards Committee (2015-2018, 2018-2022). Currently she works as a member elected of the International Medical Physics Certification Board and as chair of IOMP Professional Relation Committee (PRC). She is Fellow of IOMP (2017) and a Fellow of IUPESM (2022). [67, 73]

5.3 Clemencia García Villasmil: (1925-2000) First Woman Medical Physicist in Venezuela

Clemencia Garcia Villasmil was born in Caracas, Venezuela in 1925. She was a renowned Venezuelan and pioneer scientist who was specialized in Radiological Physics. Clemencia went to Europe when her father was consul of Venezuela in Geneva Switzerland. Clemencia studied at the Ecole Burchbül in Geneva. At the start of WWII, the family returned to Venezuela and Clemencia obtained a Bachelor of Science degree in physics and mathematics at the University of Fermín Toro in Caracas, Venezuela. Then she continued her education at the Pedagogical Institute in Venezuela. Later she went to Cuba and continued her studies at the University of Havana, Cuba.

Clemencia Garcia Villasmil then moved from Cuba to Columbia University. Clemencia was the only woman among 129 students in class of 1953. She stood out as the only woman obtaining the degrees of BSc in Physics and Doctorate in Radiological Physics. In the university there were two other Venezuelans Dr Raúl Vera Vera, distinguished Physician Radiotherapist of recognized trajectory and Dr Marcel Roche, first Director of Central University of Venezuela, International Atomic Energy (IVIC).

Dr Clemencia Garcia Villasmil was founder of Henry Becquerel Laboratory, the Radiation Physics area of the Cancer Hospital Luis Razetti in Quote, San José Parish, Caracas, Venezuela, from the José María Hospital Vargas, La Guaira, Venezuela and the Central Hospital of the Armed Forces, now Military Hospital Dr. Carlos Arvelo. In 1953, by founding the Henry Becquerel Laboratory, Clemencia became a pioneer in the provision of personal dosimetry services in Venezuela. She made treatment calculations, teaching physician specialists, and calibration of the radiotherapy units that at that time there were about thirty units throughout Venezuela.

Dr Clemencia Garcia Villasmil worked with her own equipment and calibrated them at the US National Bureau of Standards in Washington D.C., USA when the country still did not have a laboratory for dosimetric calibration.

In 1960s, Dr Clemencia Garcia Villasmil received an honorable mention from the Atomic Energy for her research work with the Cobalt units that was manufactured by Canada. Dr Clemencia Garcia Villasmil demonstrated a design failure of the Cobalt units by and presented a radiation leak that she was able to verify at the Luis Razetti Cancer Hospital which helped the manufacturer to redesign the equipment.

Dr Clemencia Garcia Villasmil directed the Radiation Physics section of the Domingo Luciani Hospital and the University Hospital in Caracas, Venezuela. At that time, she was the only non-medical teacher at UCV Hospital. She participated in various Scientific Societies. Being a founding member of the Venezuelan Society of Oncology, associate member of the Venezuelan Society of Radiology, she received many awards and honorary distinctions. Dr Clemencia Garcia Villasmil died in 2000 while she was teaching at the Hospital Universitario de la UCV. [67]

5.4 Patricia Mora: First Woman Medical Physicist in Costa Rica, ALFIM President (2022-2025)

Patricia Mora was born in Costa Rica and since her high school year's she loved physics and medicine. She graduated from the University of Costa Rica (UCR) with a Bachelor of Science degree in physics. In 1986, Patricia Mora obtained her Master of Science in Medical Physics from the University of Wisconsin-Madison, USA. Upon her return to Costa Rica, she joined the School of Physics at UCR, where she began teaching undergraduate physics courses.

Up until Patricia retirement (December 2018), she worked for more than 35 years at the UCR, where she was able to initiate and consolidate large-scale programs such as the Radiological Safety Plan, the first personal dosimetry laboratory in the country and the only radiation metrology laboratory in the country (now seeking to become a SSDL).

In 2010, Patricia Mora was co-founder the academic master's degree in medical physics at the UCR. During the period 1996 to 2018, she was a member of the Board of Directors of the Costa Rican Atomic Energy Commission where she was President for several periods. From there, she channeled and promoted IAEA technical cooperation in Costa Rica.

Patricia Mora worked on IAEA projects on issues of patient radiation protection, optimization, and quality assurance programs in mammography. Patricia Mora co-authored several IAEA books about mammography Quality Control (QC) programs. She has recently contributed to the new IAEA methodology for remote and automated QC in general diagnostic radiology and mammography. In 2019, Patricia was appointed Secretary General of the ALFIM and at is now serving as President of ALFIM (2022-2025). [67]

6.0 Pioneer Women Medical Physicists in the IOMP Regional Organizations in Asia and Oceania Region (AFOMP: Established 2000) and South-East Asia (SEAFOMP: Established 2000)

The MPI published a series of articles for these Regions. [68, 69, 70, 71, 72, 74]

As per a survey in 2014 [79] the median value of female medical physicists in Asia (AFOMP+SEAFOMP) is 35% of the professional workforce. As per data from 2015 [80] all medical physicists in AFOMP+SEAFOMP Region were c.5100.

6.1 Anchali Krisanachinda: Founding Member of Medical Physics in Thailand and First Woman President of SEAFOMP

In 1967, Anchali Krisanachinda graduated in physics from the Chulalongkorn University in Bangkok, Thailand. In 1971, she obtained her MSc in Medical Physics from the University of London, UK. In 1997, she completed her PhD from the Chicago Medical School, USA.

In 1968, Dr Anchali Krisanachinda started her career at the Ramathibodi Hospital Mahidol University, in Bangkok. From 1978 to 1981 she was Director at the School of Medical Physics at Mahidol University that had been established in Thailand (1944). Later Dr Anchali Krisanachinda worked at the Chulalongkorn University in Bangkok, where she became Professor and Head of Nuclear Medicine in 2003.

Prof Anchali Krisanachinda is founding member of the Medical Physics Club of Thailand. She has been deeply involved in promoting the development of medical physics in Asia, particularly in South-East regions. She was one of the Founding Officers of AFOMP and SEAFOMP. In 2000 she was elected AFOMP Treasurer and in 2001 she was elected SEAFOMP Vice President and served as President from 2005.

In 2000, under leadership of Prof Anchali Krisanachinda, Thailand hosted the first AFOMP Congress in Bangkok in conjunction with the IOMP/AAPM ISEP Courses/workshops. She also organized the first AOCMP Congress in conjunction with the 2nd SEACOMP in Bangkok. She also organized the 7th SEACOMP in Chiang Mai, the largest city in northern Thailand. In 2016, she also Co-organized and Co-chaired the 22nd IOMP International Conference of Medical Physics (ICMP) in Bangkok.

Prof Krisanachinda, in her own personal capacity as well as her official capacity of AFOMP and SEAFOMP, has helped medical physicists in Brunei, Cambodia, Laos, Myanmar and Vietnam to establish their own national medical physics organizations. She contributed to the development of MP profession in these countries.

Prof Krisanachinda has been serving as IAEA National Project Coordinator for Thailand under the Regional Cooperative Agreement (RCA) for the Asian Region (RAS) and has completed several projects since 1985. The projects included IAEA programs in Quality Assurance (QA) and QC, DAT and DATOL (Distance Assisted Training Online) in nuclear medicine. She has strengthened MP through Education and Training in Asia and Pacific where a structured clinical training program for medical physicists was initiated in Thailand. This was an IAEA residency training program (initially started as a pilot program in 2007 and now is a regular one) for medical physicists practicing in diagnostic radiology medical physics, radiation oncology medical physics and nuclear medicine in Thailand under Thai Medical Physicist Society and Chulalongkorn University in Thailand.

In 2005, Prof Krisanachinda was appointed as IAEA expert and consultant in the field of nuclear medicine and medical physics and took IAEA missions to several South-East Asian countries. In recognition of Prof. Krisanachinda achievements in global development of MP and her outstanding contributions to the services and activities of IOMP, AFOMP, SEACOMP and the IAEA, she was awarded the IOMP Harold Johns Medal (2018), Fellow of IOMP (2013) and of Fellow of IUPESM (2022). [69, 70, 71, 72, 73]

6.2 Agnette Peralta: Founding President of the Philippine Organization of Medical Physicists (Society of Medical Physicists, Republic of the Philippine)

Agnette Peralta, was born in Manila, Philippine. She received the Master of Science in Applied Physics (Medical Physics) Program from the University of Santo Tomas Graduate School which is the oldest and largest Catholic School in Manila, Philippine. Since 1983, she has been a faculty member at this University - the only university in the country that offers the medical physics program in the Philippines. She completed her Bachelor of Science (Physics) degree from the University of the Philippines.

Agnette Peralta received her Master of Science in Medical Physics from the University of Wisconsin – Madison, USA. She is the Founding President of the Philippine Organization of Medical Physicists, now known as the Society of Medical Physicists in the Republic of the Philippines. She was also the President of the South-East Asian Federation of Organizations for Medical Physics (SEAFOMP) from 2010 to 2012.

From 1991 to 2016 Dr Agnette Peralta served as Director of the Radiation Health Service which later became the Center for Device Regulation, Radiation Health, and Research of the Food and Drug Administration. In 2005

Dr Agnette Peralta organized the IOMP/AAPM ISEP Courses and Workshops. She retired from the Department of Health as an Assistant Secretary of Health in October 2017 and was named one of the outstanding medical physicists in the Asia-Pacific region. [69, 70, 72, 73, 74]

6.3 Djarwani S. Soejoko (1945), Founder of Medical Physics in Indonesia

Djarwani Soejoko was born in Salatiga, Indonesia in 1945. She received her Bachelor of Science and Master of Science degrees from the University of Indonesia in the field of physics of materials. She obtained her PhD in the field of biophysics from the Bandung Institute of Technology (ITB), that was established in 1920. Dr Djarwani Soejoko dissertation was titled “A study on the composition and structure of mineral compounds in the cuticle of macro brachium rosenbergii and penaeus monodon and their evolutions during the moulting period”.

Prof Djarwani Soejoko is one of the few senior scientists in the Department of Physics at the University of Indonesia. She is still active in research and teaching as well as tutoring the students in medical physics. She has published several articles in the national and international journals. She is the founder of the Medical Physics in Physics Section of the Department of Physics. For her services and dedication, she has been awarded with the “Satya Lencana Karya 30 Years”. [68, 69, 70, 72, 73, 74].

6.4 Kanae Nishizawa and Keiko Imamura: Eminent Woman Medical Physicists in Japan

Dr Kanae Nishizawa is an eminent medical physicist who graduated from Tokyo University of Science in 1973. From 1973 to 1991 she was medical physicist in Kyorin University of Medicine, Department of Radiology and from 1991 to 2010 she was working at the National Institute of Radiological Sciences, Japan. Her specialty is radiation protection and dosimetry. She has published many articles in Japanese and English. She took an active part in Japanese translation of the Scientific Dictionary of Medical Physics (www.emitel2.eu).

Dr Keiko Imamura is also an eminent medical physicist. She graduated in 1969 the Ochanomizu University and defended her doctorate in 1974 at University of Tokyo, Japan. From 1974 to 2007 she was medical physicist in St. Marianna University Hospital, Department of Radiology. Her specialty is Physics of Diagnostic Radiology and Magnetic Resonance Imaging (MRI). She has published many articles in Japanese and English. She also took active part in the Japanese translation of the Scientific Dictionary of Medical Physics (emitel2.eu). [58, 71, 74]

6.5 P.N. Manorani Vijayam – Eminent Woman Medical Physicist in India

Dr P. N. Manorani Vijayam is one of the first women medical physicists in India, who started her career in 1960s (also in the 1960's started her careers Sharada K.S. and Reshamwala H.H.). Dr Vijayam completed the Diploma in Radiological Physics (DipRP) from Bhabha Atomic Research Centre (BARC), Mumbai in 1967. She joined the Radiation Standards Section of BARC in late 1968 and continued working there for 33 years, until 2002. She was associated with development of ionometric standards for Co-60 teletherapy beams which was used by BARC for a long time. She was also associated with conducting the dosimetry audit in beam therapy. In addition, she was involved in calibration of radiotherapy dosimeters of the hospitals. Dr. Vijayam was also involved in teaching and training of DipRP students and trainees. [71, 73]

6.6 Parvaneh Shokrani (1959): Frist Woman Medical Physicist from Iran

Prof Parvaneh Shokrani was born in Isfahan, Iran in 1959. She completed her high school education in 1980, majoring in mathematics. She then completed her undergraduate physics education at University of Isfahan, in Isfahan, Iran in 1985. She then went to University of Cincinnati in Ohio and completed her MS degree in health physics and radiation protection in 1988. Later, she completed her PhD in medical physics, specializing in physics of radiation therapy from University of Cincinnati in 1992. Her PhD research thesis was “Application of Monte Carlo Simulation of Total Skin Electron Therapy for Treatment Optimization”.

Prof Parvaneh Shokrani taught medical physics and did research for many years at Isfahan University in Iran. She has been author and co-author of 55 peer-reviewed scientific articles. She has written couple books in portal design and imaging and radiation protection. In 2013, Dr Shokrani registered her patent in Iran on “A novel treatment method for lip carcinoma using an internal dose enhancer tool”. Dr. Shokrani has received many honors and awards, including University-wide investigator of the year award Isfahan University of Medical Sciences, Isfahan, Iran (2013).

6.7 Eva Bezak from Australia, First Woman President of AFOMP

Prof Eva Bezak, FACPSEM, FIUPESM holds MSc in Medical Physics (University of Adelaide, 1994) and PhD in Nuclear Physics (Australian national University, 1998) and is an internationally known medical physicist and Professor in Medical Radiation at the University of South Australia (from 2015). Prior to 2015, she spent 17 years in industry as a medical physicist at the Royal Adelaide Hospital (RAH), becoming Chief in 2006. She was the first female president of the Australasian College of Physical Scientists and Engineers in Medicine (ACPSEM; 2010-2012), she secured \$5.5M of government funding for an Australian medical physics training. In 2015 she was appointed to the Administrative Council of the International Union for Physical and Engineering Sciences in Medicine (IUPESM) and was founding member of the IUPESM Women in Medical Physics and Biomedical Engineering Task Group. In 2017 she became the first female Vice president (now President, 2023) of the Asia-Oceania Federation of Organizations for Medical Physics (AFOMP). In 2019 she was appointed the Secretary General of the International Organization for Medical Physics and was elected the IOMP Vice-President in 2022. She is a convenor for the IUPESM World Congress 2025, to be held in Adelaide, Australia.

Prof Eva Bezak is a co-author of the Australian Academy of Science Report on future accelerators in Australia (2016) informing the government on the need for proton therapy and a past member of the National Radiation Oncology Tripartite Committee that developed quality and performance standards for radiation oncology in 2012 directly impacting the quality and the delivery of radiation oncology services in Australia. She co-authored the Tripartite National Plan for Radiation Oncology 2012-2022 as well as the National Needs Analysis Survey, examining accessibility to antenatal ultrasound and training in rural Australia (2022). Additionally, she is author of over 200 publications and 3 books and has supervised over 40 research postgraduate students (MSc, PhD).

In 2019 she was included in the South Australian Women's Honour Roll, tributing South, Australian women who have made a significant impact on the community, women who are role models and leaders. [71, 73]

6.8 Hasin Anupama Azhari from Bangladesh – First Woman Secretary General of AFOMP

Prof Hasin Anupama Azhari was born in Bangladesh and awarded PhD in Medical Physics from National University in 2011 in collaboration with OWSD, ICTP, Trieste, Italy. Her research station was in Zhejiang Cancer Hospital, China and German Cancer Research Centre (DKFZ). She became the Chairman of Medical Physics and Biomedical Engineering Department, Gono University (GU) as well as Dean, Faculty of Physical and Mathematical Sciences, GU and made her efforts developing medical physics education there until 2021. Currently, she is serving as Director of the Centre for Biomedical Sciences and Engineering at the United International University (UIU), Dhaka, Bangladesh. She has academic experience more than 15 years in medical physics field.

Prof Hasin Anupama Azhari has published more than 50 research works in different national and international journals and books. She has participated and organized various workshops, training programmes, conferences in different countries. Prof. Azhari has been playing an important role in cancer screening and awareness programme and arranging of accredited training program for cancer professionals for the SA regions through the South Asia Centre for Medical Physics and Cancer Research (SCMPCR) under Alo Bhubon Trust. Prof Azhari is an Executive Member of OWSD (Asia and Pacific Region), Secretary-General of AFOMP (2019-2022) and Vice-President of AFOMP from 2022. She is the founder President and advisory member of Bangladesh Medical Physics Society (BMPS), Secretary General, Alo Bhubon Trust, Vice President, Bangladesh Association of Women Scientists (BAWS), Regular Associate, ICTP, Association of Medical Physicists of India (AMPI), Life-time Member, Bangladesh Physical Society (BPS), Member of ESTRO, AAPM.

Prof Hasin Anupama Azhari is the first woman Medical Physicist in Bangladesh with MSc in MP, she has communicated with the health ministry and other government, nongovernment organization to publicize of the subject. In her tenure in BMPS she assisted and worked with Directorate of Health Services and Ministry of Health to create GO and recruitment rules for medical physicists and till now trying the MP order for public hospital to be gazette.

Prof Hasin Anupama Azhari has received International Medical Physics Day Award, IOMP in 2018 and Outstanding Medical Physicists Award, AFOMP, 2020. She was a project coordinator for Bengal translation at EMITEL e-Encyclopaedia of Medical Physics and Multilingual Dictionary and terms. She also acts as a PD for the student teacher exchange program between Heidelberg University Germany and GU through DAAD scholarship for 8 years. [58, 71, 73]

7.0 Pioneer Women Medical Physicists in the IOMP Regional Organization in Middle East Region (MEFOMP – Established 2009):

The MPI published several articles focused on the development of Medical Physics in the Middle East Region. [75, 76]

As per a survey in 2014 [79] the median value of female medical physicists in the Middle East is 50% of the professional workforce. As per data from 2015 [80] all medical physicists in the MEFOMP Region were c.600.

7.1 Hanan Rima: First Woman Medical Physicist in Lebanon

In 1984 Dr Hanna Rima received her PhD in Radiological Medical Physics from University Paul Sabatier, France. Then Dr Hanna Rima worked as Chief Medical Physicist at the North Hospital Centre in Lebanon.

7.2 Huda Al Naemi: First Woman Medical Physicist in Qatar, First Woman President of MEFOMP (2018 – 2022)

Dr Huda Al Naemi, completed her PhD in Qatar in 1999. Dr Huda Al Naemi has served as the first Inaugural Secretary-General of MEFOMP. Since 2006, Dr Huda Al Naemi has served as the President of Qatar Medical Physics Society (QaMPS). She also served as the first President of MEFOMP (2018 – 2022). Dr Huda Al Naemi is the Executive Director of Occupational health and safety since 2006. Dr Huda Al Naemi has been an affiliated Assistant Professor in the Weill Cornell Medicine in Qatar since 2019.

Dr Huda Al Naemi has received the State Encouragement Award for Medical Sciences Category in 2017. Dr Huda Al Naemi has also received the Healthcare Gold Medal from the Institute of Physics and Engineering in Medicine (IPEM) in 2019.

7.3 Jamila Al-Suwaidi: First Woman Medical Physicist in United Arab Emirates

Dr Jamila Al Suwaidi received both MSc and PhD in radiation physics from the University of Surrey, UK. Dr Jamila Al Suwaidi was the first medical physicist in the United Arab Emirates and she became the first President of Emirati Medical Physics Society (2005-2009). She is the first Emirati specialist to obtain postgraduate qualifications in the field of medical physics. Dr Jamila Al Suwaidi received the UAE Presidential Award in Sciences in 2012.

7.4 Laila Al Balooshi: First Woman (inaugural) Secretary General of MEFOMP from United Arab Emirates

Ms Laila Al Balooshi from the United Arab Emirates is experienced medical physicist with a distinguished history of working in the hospital and healthcare industry. She is Head of Medical Physics Section, Dubai Hospital in Dubai Health Authority. Ms Laila Al Balooshi was the first Secretary-General of MEFOMP (2015-2018).

7.5 Shada Ramahi: First Woman Medical Physicist in Jordan

Dr Shada Ramahi is Jordanian medical physicist in radiation oncology. She is the first woman medical physicist in the region to be examiner in the International Medical Physics Certification Board (IMPCB) since 2019. She was working as Chief Medical Physicist in King Faisal Specialist Hospital & research Centre, Saudi Arabia. In March 2020, Dr Shada Ramahi moved to USA as clinical Associate Professor at the University of Pittsburgh, Pennsylvania, USA.

8. Pioneer Women Medical Physicists in the IOMP Regional Organization in Africa (FAMPO Region – Established in 2009)

The MPI has published several articles focused on the development of Medical Physics in the African Region (FAMPO). [77, 78]

As per a survey in 2014 [79] the median value of female medical physicists in Africa is 33% of the professional workforce. As per data from 2015 [80] all medical physicists in the FAMPO Region were c.400.

8.1 Boutayeb Salwa: Senior Woman Medical Physicist from Morocco

Boutayeb Salwa started her medical physics career in 1993. She completed her engineering degree from the National Institute of Nuclear Sciences and Techniques of Cadarache, in France, and her PhD from the Atomic Physics Center of Toulouse University, in France.

Dr Boutayeb Salwa is Senior Medical Physicist and is now serving as the Head of Medical Physics section at the National Oncology Institute of Rabat in Morocco. In addition, Dr Boutayeb Salwa provides Education and Training in Medical Radiation Physics for Moroccan and foreign medical physicists. She is an IAEA expert and has coordinated couple projects in African countries that are affiliated with FAMPO.

8.2 Nadia Khelassi-Toutaoui: First Woman Medical Physicist from Algeria

Nadia Khelassi-Toutaoui started her career in 1995 at the CRNA Centre in South Africa. In addition, she has involved in academic and has taught practical training courses to students. Dr Nadia Khelassi-Toutaoui is currently working at the School of Nuclear and Allied Sciences, University of Ghana in Ghana.

8.3 Zeinab Eltaher: Eminent Medical Physicist from Egypt

Dr Zeinab Eltaher graduated in 1977 from the Faculty of Science, Cairo University, Egypt. She started her work at National Cancer Institute, Cairo University in 1978 and gained her PhD. She was the first to apply the total skin treatment at the National Cancer Institute, Egypt. Dr Zeinab founded medical physics sections in various Egyptian Governorates. Her contributions to developing the quality of radiotherapy treatment in Egypt continue until now and she has many publications. Recently she led a team of distinguished physicists to establish a radiation oncology department with most recent technology.

8.4 Rebecca Nakatudde from Uganda: First Woman FAMPO Vice-President

Mrs Rebecca Nakatudde works as a Medical Physicist at the Makerere University, College of Health Sciences, in Uganda. She was the first African woman speaker at the IOMP Project on medical physics development in Africa (ICMP 2013, Brighton, UK).

9. CONCLUSION

Together with bios of the pioneer women scientists with special contribution to physics, which reflected in medical physics, the paper includes short bios of 36 pioneer women medical physicists from IOMP Regional Organisations in all continents (EFOMP, ALFIM, AFOMP, SEAFOMP, MEFOMP, FAMPO) and North America. The indicative samples/bios were chosen from various types of societies. The paper lists only some early women medical physicists per Regional Organisation (RO), leaving to each RO to create a full list of all pioneer women medical physicists from each IOMP National Member Organisation (NMO). Such future survey(s), combined with all first colleagues in each NMO, will form a very valuable record of the historic development of our profession, thus tracing vectors for development in the future global professional development and recognition of medical physics.

During the 60 years of its activities, IOMP helped many countries, especially in the Low-and-Middle Income Regions to start their medical physics activities, to organize educational courses and training programmes, to boost their contribution to the overall development of global healthcare. This history paper shows an important part of this progress, associated with the involvement of women in this contribution. The paper was planned to cover the period to 2018, while the new plans and activities of the IOMP Women Sub-Committee (WSC) will be presented in a separate paper, led by L Marcu, the current Chair of WSC.

The authors of the paper are from the IOMP History Sub-Committee (HSC) and have led the presentation of IOMP History over the years, plus the development and update of the IOMP History Tables, including the names of all colleagues contributing to IOMP activities during the past 60 years. A recent publication of the MPI Journal includes all these history articles [81].

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Contact authors:

Azam Niroomand-Rad (parts 1,2,3,4,6) email: azam@georgetown.edu

Slavik Tabakov (parts 1,4,5,6,7,8) email: slavik.tabakov@emerald2.co.uk

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