Special topic

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Encounters with successful women scientists

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Abstract: There are many greats in science history but relatively few women scientists that could be chosen as role models. This essay presents some from among contemporary contributors to chemistry, biochemistry, biology, physics, and astronomy. They had overcome barriers of discrimination, the difficulties of managing their time between research and family, and all have triumphed. They include some of the most famous, such as Isabella Karle, Christiane Nüsslein-Volhard, Anne McLaren, and Vera Rubin, and some less famous, including examples from Russia, India, and Turkey. Their presentation is based on personal encounters with them by the author; herself a scientist, wife, and mother.

Keywords: Anne McLaren; Christiane Nusslein-Volhard; Distinguished Women in Chemistry and Chemical Engineering; Frances Kelsey; Isabella Karle; Mildred Dresselhaus; role models; women scientists.

I should probably explain why I am writing about other scientists rather than myself – as we were asked to do in the kind invitation by IUPAC. My reason is simple: during the past couple of decades, I have had personal encounters with many famous women scientists and I thought this experience is worth sharing. Their life stories, successes, difficulties, and the way they overcame all hurdles are not only interesting but also might give strength to those women who love science and research, but may sometimes feel overwhelmed by all the challenges they have to face.

All this started many years ago. My husband, also a chemist, started recording conversations with famous scientists. I found the interviews so exciting and stimulating that I decided to join him in this "hobby," and, eventually, our chemist son became a member of our team. The result was hundreds of interviews with chemists, physicists, biologists, biomedical scientists, mathematicians and so on. We hoped that these in-depth conversations would bring these successful individuals and their science into human proximity. The result was the six-volume book series, *Candid Science*, published by Imperial College Press [1]. It provided a good cross-section of scientific progress mostly in the second part of the twentieth century.

We were well into this project when I began noticing the underrepresentation of women in our "collection." There were only about two or three among the 36 interviews in each of these volumes. I must confess that I had never before considered "women in science" as an issue. I was always busy with my research, with bringing up our children, the household-duties, and our book-writing activities. Besides, I myself had never felt discrimination as a scientist due to the fact that I am a woman – today I understand how lucky I have been.

After noticing the serious underrepresentation of women in our project – as it reflected their underrepresentation in the higher echelons of science – I decided to look into this problem. I started interviewing successful women scientists and recorded our conversations about their careers and concerns. Some of these women decided at one point in their career that they would take another challenge, and became leaders of science institutions. This aspect is of additional interest, because such leadership roles have also been traditionally male dominated. I started giving talks about women scientists and the interest these talks generated encouraged me to continue my project. At some point, I decided to write a book based on my interviews [2].

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As I was organizing my book, I was pleasantly surprised by the richness and the diversity of the material I had collected. The interviewees were from 18 countries on four continents and from a broad variety of scientific fields. I was especially happy to have collected conversations with successful women scientists from countries about whose women scientists information is rather scarce, viz., Russia, India and Turkey.

Below I will try to give a glimpse into the lives and thoughts of some of these women scientists. How could they make it in spite of all the difficulties and hurdles, none of which their male colleagues usually face. I hope that the following will give some answers to this question.

From left to right starting from the top: Isabella Karle, Frances Oldham Kelsey, Christiane Nüsslein-Volhard, Elena G. Galpern, Charusita Chakravarty, Ayhan Ulubelen, Rita Cornforth, Mildred Cohn, Anne McLaren, Shirley M. Tilghman, Mildred Dresselhaus, Vera Rubin. All photographs by the author, © Magdolna Hargittai.

Isabella Karle, crystallographer

I am especially happy writing about Isabella because she and her husband, Jerome, were our friends for decades. They are among the pioneers of the field in which my husband and I have been involved during our careers; the determination of molecular structure, primarily by gas-phase electron diffraction. I met them for the first time at an international meeting in southern Hungary in 1978 and from the first moment, we found a common language.

Isabella (1921–2017), with a fellowship, went to the University of Michigan for her doctoral studies. There, she met Jerome Karle (1918–2013) and they got married during their PhD studies. In 1946, they both joined the Naval Research Laboratory, and stayed there until their retirement in 2009.

During their career, they mostly worked together; Isabella characterized this as "we worked together separately". By this she meant that they worked on the same or similar problems but from different angles, and they complemented each other. Actually, this is what made many famous scientific couples successful. In their case, Jerome worked mostly on theory and she was the experimenter. Isabella told me: "For much of what Jerome does, he would like to have experimental examples and he uses the results of many of the structures that I have determined. This has not happened by design but it turns out that way [3]".

With time, Jerome moved more and more towards theory and Isabella stayed with experiment. Jerome, together with the mathematician Herbert Hauptman, developed the so-called "direct method," that made possible the accurate determination of the structures of much larger molecules by X-ray diffraction than ever before. Eventually, in 1985, this brought Herbert Hauptman and Jerome Karle the Nobel Prize in Chemistry "for their outstanding achievements in the development of direct methods for the determination of crystal structures" [4]. Many people think that Isabella should have been included in the prize; Jerome, in fact, was devastated when he learned that she was not included.

We should add that the recognition of the importance of the direct method did not come right away. Initially, most crystallographers did not accept the idea and did not even try to apply the method. Isabella, however, recognized its usefulness, and started to determine the structures of large molecules, with around 50–60 atoms, that used to be considered impossible. Many scientists working in related areas commented that she should have been among the Nobel Prize winners. After all, it was Isabella, who worked out the so-called "symbolic addition procedure" that established the connection between the theory and the actual crystal structure determination. Isabella considered this to be her most important achievement [5]:

> It was certainly pleasing to be able to put crystal structure analysis on a practical basis. Of course, Jerome and Herb Hauptman developed the theoretical work. However, there was a very definite step between having an infinite set of inequalities and having a set of real data with experimental error … It was very satisfying when I was able to present schemes of operation first for the direct determination of centrosymmetric structures and then for non-centro-symmetric structures. It's also pleasing that all these procedures have now become commonplace…

Isabella received many recognitions, among them the prestigious US National Medal of Science and the coveted Aminoff Prize from the Royal Swedish Academy of Sciences given to pioneers in crystallography. She was the first woman to receive the Bower Award and Prize for Achievement in Science from the Franklin Institute. At the time of their retirement in 2009, both she and her husband received the Distinguished Civilian Service Award, the highest recognition by the Navy that a civilian employee can receive.

Frances Oldham Kelsey – "Heroine of FDA"

When Frances Kelsey (1914–2015) died, *The Washington Post* together with other leading newspapers in the US published an obituary of Frances Kelsey [6]. The origin of her fame dated back 53 years earlier, when *The Washington Post* and other leading papers first wrote about her [7].

Kelsey was born in Canada. After receiving her BA degree from McGill University, she moved to the University of Chicago for her PhD. At that time, Chicago did not have female doctoral students and her application was also considered as coming from a Francis (rather than Frances). When she was accepted and appeared in person, she was not refused [8]. After receiving her PhD, she also got a medical degree. When her husband received a job offer from the NIH (US National Institutes of Health), she got a position at the FDA (the US Food and Drug administration) and they moved there.

This was at the time when an American drug company submitted an application for marketing a drug, thalidomide that under the trade-name Contergan had been very successful in Europe for years. It was used as a sedative and also as a palliative for women experiencing morning sickness during the first trimester of their pregnancy. The drug company did not expect any difficulty in receiving the permission. This did not happen, due to Kelsey's and her colleagues' careful investigation. They found many problems with the application; e.g. the company did not indicate which chiral form of the molecule they used, or perhaps a racemic mixture. Kelsey asked for further investigations and the company repeatedly complained to her boss about the slowness of processing the permission. However, she insisted that everything had to be checked.

Eventually, news started arriving in America about an increasing number of malformed babies born in Europe. Soon, it became clear that the culprit was thalidomide. It was found that one of its two chiral forms was teratogenic – and the teratogenic effect could not be assigned to only one form as the forms rapidly interconvert in the organism. When all this became known, Kelsey suddenly became famous and deservedly so. Her resilience not to bend under the constant pressure of the drug company was now recognized and appreciated. It is no exaggeration that she saved thousands of babies from devastating birth defects.

Back in 1962, according to a Gallup poll, she was among the most admired women in the world, together with such celebrities as Queen Elisabeth II and Jacqueline Kennedy [9]. Kelsey received the Distinguished Federal Civilian Service Award from President Kennedy. Her merits are in "her dual role in saving thousands of newborns from the perils of the drug thalidomide and in serving as midwife to modern pharmaceutical regulation [10].

Christiane Nüsslein-Volhard, developmental biologist

Christiane Nüsslein-Volhard (1942–) has been involved with research in developmental biology during her entire career. How successful she was in this is shown by the fact that she, together with Eric F. Wieschaus and Edward B. Lewis, shared the 1995 Nobel Prize in Physiology or Medicine "for their discoveries concerning the genetic control of early embryonic development." [4].

She received her PhD degree at the University of Tübingen. She wanted to find a research field which was new and where she could rely on her experience in molecular biology and DNA replication. Developmental biology seemed to be an interesting possibility. She soon moved to the European Molecular Biology Laboratory in Heidelberg. There, with an American colleague, Eric Wieschaus she started a new project, using *drosophila* (fruit flies). Christiane explained to me that *drosophila* were ideal subjects for their research because their larvae have fourteen seemingly equal segments, still they develop into different parts of their body. How do these segments know what they are supposed to develop into? With hard work, Nüsslein-Volhard and Wieschaus identified which ones were responsible for the growth of the different parts of their body. This is what they eventually received the Nobel Prize for.

When I asked Christiane whether she has ever experienced discrimination because she is a woman, she answered emphatically [11]:

> Oh, yes, plenty! .... I have to say that my science was never discriminated against. So I had no problem whatsoever in getting my science recognized. But in the practical aspects, to get jobs, to get money, to get lab space, women have not been treated equally.
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> At the time when I was a young scientist, men often had family and children and they got the better positions automatically. The professors always said, "but this is a man, he has to support and nourish a family, so this is why he is going to get the

> job and you will not." This happened repeatedly to me. The same thing with promotions. They often said, you are a woman and there is a man and he deserves it more.

I asked her whether in her opinion a woman has to work harder to get the same recognition as a man [12].

> At least she can't afford to make mistakes, at least not as much as men. … In particular when women are aggressive, people don't like that at all. When men are aggressive, it is perfectly normal; it belongs to their normal habit. When a woman is aggressive and behaves in the same situation as a man would, they always charge that against her. This is bad because aggression in a positive sense is absolutely necessary to succeed in a job. You have to push your point and not that of your neighbor. Unfortunately it is part of the profession.

Christiane is still very active; as an emeritus professor she leads a research group at the Max Planck Institute of Developmental Biology. She is also concerned with the question of women in science. Years ago, she started a foundation to give grants to young talented women with children, to pay for household help.

Russian women scientists

We know about some famous women scientists in Russia from the late nineteenth century, the best known being the mathematician Sofia Kovalevskaya. However, there is hardly any information about women scientists following the 1917 Bolshevik Revolution and, similarly, in the post-Soviet era. The scholar Olga Valkova writes: "… aside from a few brief articles, there has been nothing at all about the 'woman in science' question since 1917; because there was no 'woman's question' in the USSR, there was nothing to talk about" [13]. Theoretically, women had equal rights with men and all professions were open for them; but if there were problems with equality, they could not be discussed.

I talked with several successful women scientist in Russia, some of them are members of the Russian Academy of Sciences, occupy important positions, and carrying out outstanding research. I mention here only one of them, Natalia Tarasova, past president of IUPAC, who was able to occupy important positions, found new research institutes, and carry out her own research.

There is one particular point I would like to bring up in connection with Russia – or, rather, the former Soviet Union. This is the flow of information – or, rather, the lack thereof – from and to the Soviet Union. Since the Soviet scientists operated in near hermetic isolation, even when they "discovered" something, it may have happened that it had already been discovered in the West, but the Soviet scientists might have not known about it. Conversely, when Soviet scientists did discover something, their colleagues in the West might have not learned about it and might have had to discover it anew. I mention here one example involving a woman scientist.

Elena G. Galpern, computational chemist

During the 1970s, Elena (1935–) was a young computational chemist working for her PhD equivalent degree in one of the research institutes of the Soviet Academy of Sciences. She was doing rather sophisticated quantum chemical calculations for the time. Her task was to design cage-like molecules consisting of carbon atoms that could accommodate atoms of different elements or even small groups of atoms. After trying many models, she came up with the idea of a cage molecule of 60 carbon atoms, in the shape of a truncated icosahedron, that appeared to be stable. The paper on this research appeared under the names of Elena Galpern and her mentor, D. A. Bochvar in a leading Russian periodical, in 1973 [14]. Although an English translation of the journal made the article accessible also for non-Russian readers, the discovery went unnoticed both in the Soviet Union and in the rest of the world. As is well known, about a decade later, in 1985, a team of scientists at Rice University observed the stable C_{60} molecule in an experiment. They suggested the truncated icosahedral shape for it, and called it buckminsterfullerene [15]. In 1996, they received the Nobel Prize for their discovery.

Eventually, these researchers found Galpern's calculations in the literature (and also a suggestion by a Japanese scientist, Eiji Osawa, concerning the stability of this molecule). For a short while, Galpern received a great deal of publicity, which then subsided. Imagine, if she could have traveled to an international conference in the mid-1970s and called attention to the truncated icosahedral C_{60} molecule. Her career might have made a different turn, and fullerene chemistry might have started a decade earlier.

Indian women scientists

In 2011, I had the privilege of visiting leading universities in India and to meet several highly successful women scientists, some of them members of the Indian Academy of Sciences. I talked with these women about the status of women in Indian society as well as about their experiences as scientists. All agreed that they are probably the exception rather than the rule, because the woman's primary role in Indian society is in family responsibilities [16]. For girls, the number one objective is to marry and take care of their husband and the children. There is also the sentiment, especially among the older generation, that it does not look good for a man if his wife works because it suggests that he is not able to provide for his family.

At the same time, at least in some segments of the society, women are expected to be intelligent and well educated and they do go to college. In middle-class families, the parents want their daughters to get a higher education before they get married because it is considered that smart women make good mothers. There is a great demand for good schools and there is increasing competition for a good education, even at the level of the elementary school. In order to get in, the children have to pass demanding entrance examinations. The schools interview the parents as well. The father is expected to be highly educated with a good job. The ideal mother is also expected to be highly educated, *but* she is not supposed to have a job. The idea is that the mother should spend all her time at home rearing the children. It is not only the schools that look for such ideal mothers, but many men look for such women to marry them. I introduce here only one of my Indian interviewees, Charusita Chakravarty.

Charusita Chakravarty, chemist

Charusita Chakravarty (1964–2016) had a rather unusual background; she was born in Cambridge, MA, where her parents worked as professors at the time. Eventually, the family moved back to India and when the time came for Charusita to decide on her citizenship, she opted for India. This was a far-reaching decision and she did not take it lightly. She wrote in a book about women scientists in India [17]:

> … I found myself comparing the nature of intellectual marginalization based on gender since I was working in a developing country. Clearly, both factors can distance you considerably from the mainstream of scientific activity and can lead to considerable skepticism as to the worth of one's contributions, both in one's own mind as well as that of one's professional peer group. … At personal level, being an "Indian" and a "woman" are as intrinsic parts of my identity as my interest in doing science and therefore … I have tried to integrate and do some justice to these different aspects of my identity. In the context of our society, getting the opportunity to do so is quite fortunate.

Charusita and her husband have one daughter. They had been lucky for a while because they worked in the same city. I found that getting a job in the same city as the one your spouse was working is one of the most serious problems for the women I talked with. Eventually, however, they also had to face this problem, as her husband became vice chancellor of the University of Hyderabad, about 630 miles from Delhi, where she worked.

Charushita was a professor at the Indian Institute of Technology, in Delhi. Her interest was in theoretical chemistry and chemical physics; she was involved with different topics; for example, with studying the anomalous properties of water. She received prestigious awards for her work and was elected to be a member

of the Indian Academy of Sciences. She had a most promising career – but then she became ill and after a long and difficult period, she passed away in 2016. She was a highly intelligent and talented woman whom I feel honored to have known.

Turkish women scientists

In 2008, I was invited to give a talk at a conference on Women in Science at the Istanbul Technical University. I noticed with surprise that it is not uncommon in Turkey that a woman holds the position of rector (president) of a large university, and there are quite a lot of women professors at the universities. Turkey is a predominantly Muslim country with a history of centuries of polygyny[1] back in the Ottoman Empire. Considering the patriarchal cultural heritage of the country, one would not expect women to occupy important positions in society. The reasons for their conspicuous presence in university life are rather complex and are beyond the scope of this present writing [18]. Let me mention just one of the reasons: according to the author Kagitcibasi, in society's eyes there were no appropriate or inappropriate jobs for women because earlier they were not allowed to work outside the home in the first place. Thus, in the new world women could choose even professions that in the West were traditionally looked at as "unfeminine" [19]. This is why there have been more women in engineering than in most Western countries. As to finding a relatively large number of women as successful science administrators, the women I talked with agreed on a not too encouraging explanation. They think that positions in science and higher education may not be sufficiently attractive for men and therefore they do not mind if women occupy them.

Ayhan Ulubelen, chemist

The journal *Phytochemistry Letters* celebrated Ayhan Ulubelen's (1931–) 80th birthday with a special issue. In its introduction, the guest editors describe Ulubelen as "one of the pioneers in scientific research in Turkey and a world-wide recognized authority in Natural Products Chemistry" [20]. There was also a conference celebrating her anniversary and the 60 years of successful research in this field although for most of her career, she worked under much poorer conditions than most of her colleagues in the West.

She received her PhD from the Faculty of Pharmacy at Istanbul University and spent all her life at this institution, except for short periods at different universities in the US and elsewhere. Having chosen natural products chemistry as her research field was most fitting, considering the importance of using natural remedies, often ancient cures, for different ailments in Turkey. She and her colleagues investigated indigenous plants and identified the ingredients that could be assigned to specific physiological effects. One example is the plant that used to be taken by pregnant women to cause spontaneous abortion. They examined different parts of the plant and the follow-up studies showed that mice they administered the extract of this plant to, developed cysts in their ovaries and had other problems as well. Therefore, they could not suggest this plant as an abortive agent; on the contrary, women had to be warned of the hazards of its use and the suggestion was to avoid using it.

She used to be a member of the Turkish Academy of Sciences; used to be, because together with several other colleagues of hers, she resigned in 2011. This was a form of protest against a decision of the government, according to which the government would appoint two thirds of the academy leadership. Those academicians who resigned founded the Science Academy Society, an independent civil-societal organization to promote scientific merit, freedom, and integrity.

1 "Polygyny" means one man having multiple wives. The better known word "polygamy," strictly speaking, refers to one person having multiple spouses.

Work and family – can it be both?

I asked all my interviewees about the greatest challenge in their career. Almost all of them said that having a family with children and doing science at the same time is the greatest problem. The comments below speak for themselves.

Rita Cornforth, chemist

Rita Cornforth (nèe Harradence, 1915–2012) was a British chemist. She worked together with her husband, John Cornforth (1917–2013) all her professional life. They both were born in Australia, and after their graduation, they went to Oxford to work with Robert Robinson, future Nobel Laureate organic chemist. The Cornforths were very successful in their research; John Cornforth received the 1975 Nobel Prize in Chemistry "for his work on the stereochemistry of enzyme-catalyzed reactions" [4]. John said in his Nobel lecture: "… my wife Rita Cornforth, with patience and great experimental skill, executed much of the chemical synthesis on which the success of the work was founded. To her, in this as in other ways, I owe more than I can well express [21]."

Rita was an especially skilled chemist. Her most important work was the part she played in the elucidation of the stereochemistry involved in the biosynthesis of cholesterol. Her expertise included isotope labeling that had a crucial role in the work. I also have to mention that her husband lost his hearing completely when he was a teenager and he never learned lip reading. Thus, Rita served, so to speak, as his ears as well.

They had three children. When I asked her how she managed, she said: "It was difficult, of course, and by the time I had three children I sometimes thought: 'If I hadn't embarked on this I wouldn't, but I can't give up now.' I was not a superwoman and could not have combined an independent career with bringing up children. It was possible because we worked so closely together. I found it easier to put chemistry out of my mind when I was at home than to put the children out of my mind when I was in the lab [22]."

Mildred Cohn, biochemist

Mildred Cohn (1913–2009) was an American biochemist. She graduated from Hunter College in chemistry and wanted to go to graduate school but all 20 universities she applied to rejected her. Women were not welcomed as graduate students those days. She took a job to finance her studies and went to Columbia University, where Harold Urey was her mentor. She was lucky to be able to work with him and with other famous scientists, such as Vincent du Vigneaud at Cornell and Gerty and Carl Cori at Washington University; all of them later became Nobel laureates. Eventually, Mildred received a position at the University of Pennsylvania. She was an expert in phosphorous-31 NMR spectroscopy, studying, among others, the enzyme reactions of ATP. I visited her at her office at the University of Pennsylvania in 2002.

Among others, she told me how difficult it was for her to be a mother and a scientist at the same time; it just was not generally accepted that women with children worked [23]:

> The chairman of the chemistry department at Hunter College had told us that it wasn't ladylike for women to be chemists. … He wanted us to be teachers of chemistry. I got a lot of criticism from relatives. A great-aunt said that I would educate myself out of the marriage market. After I had my first child, my mother-in-law carried on a campaign to get me to quit working, but she didn't succeed either. … There was a lot of social pressure against the mothers working.

When her oldest daughter was 7 years old, she was the only one in her school whose mother worked outside the home. Someone told her that she has a bad mother, and the little girl complained about this at home. This daughter eventually became a psychologist and wrote a paper about the effects on children of having a working mother versus a nonworking mother. Her conclusion was that there was no appreciable difference.

Anne McLaren, developmental biologist

Anne McLaren (1927–2007) became interested in genetics during her studies at Oxford, and so did another student, Donald Michie. After receiving their doctorates, they got a joint grant to work at University College London; and also they got married. Their joint work brought about much success. Their task was to study maternal effects between two inbred strains of mice. Eventually, Anne and another colleague, John Biggers, cultured embryos and transferred them into the uterus and mice were born. This was the first time that embryos, kept outside the body for 24 h, had been successfully reared into parenthood. Obviously, this result made the headlines. As a consequence of their work, in 1978, the first human "test-tube baby" was born. It became clear that they had to consider the enormous ethical and social implications of their work. Committees were formed, in which McLaren was the only biologist. She was a leading figure in formulating the guidelines for the Human Fertilisation and Embryology Act.

She had three children and she had her share of difficulties [24]. "As a research scientist, the hours are flexible. When the babies were young I used to take them into the lab." Later, she found au pair girls to take care of the children. Still, when I asked her what the most difficult aspect of being a mother *and* a scientist was, she answered: "Time. Time. Organization of time."

Shirley M. Tilghman, molecular biologist

For 11 years, from 2001 till 2012, Shirley Tilghman (1946–) served as the first female president of Princeton University. I visited her during her first year and thus it was an obvious question to ask: what was behind her drive to take this job when she was in the middle of a successful career as a scientist? She just recently founded a new institute; the Institute of Integrative Genomics. She had a large number of students at different stages of their studies. Why? Her answer was that she had enough self-confidence to believe that she would be able to do the job. She was right. A lot of changes happened at Princeton during her tenure, among them changes to help young women during their doctoral or post-doctoral studies if they had a baby during this period.

Shirley had two children; she brought them up as a single mother. Concerning overcoming the difficulties, she said. "I think, I managed by denying that there was a problem. If I had allowed myself to really see how difficult what I was doing was I would have just collapsed." She did not have hired help, "because I never had enough money for that. I was living on one salary, I was not getting any child support; he just did not pay and I just decided that it was not worth going to court and becoming obsessed with this [25]."

Mildred Dresselhaus, physicist

Millie Dresselhaus (1930–2017) graduated from Hunter College in New York. Hunter at that time was a women's college, and women who were talented and passed a serious entrance examination were accepted without tuition. Many Hunter graduate women have become very successful in their fields. For Millie, one of her teachers, Rosalyn Yalow (a future Nobel laureate physicist) was a great influence. Millie received her PhD from the University of Chicago with an advisor who was very much against women in science; he considered this a waste of resources. She met her future husband, Gene Dresselhaus, also a physicist, there. They had problems in finding a job because of the anti-nepotism rule that did not allow for husband and wife work at the same university. Eventually, she found a job at MIT and stayed there for her entire carrier. She became very successful for her work in carbon science. She received many awards and recognitions; the highest among them being the Kavli Prize, for her work in nanoscience, in 2012. The award money, one million dollars, shows the seriousness of the award.

Millie had four children and she had great difficulties at her work when the children were young. This is what she said about this [26]:

There was always a problem in organizing one's family in the morning. My supervisor at Lincoln Lab complained about me so much that I got tired hearing of all the complaints, because I was doing the best that was humanly possible. So I was looking for a year off from all this unpleasantness in my life. It wasn't that I wasn't productive; nobody ever complained about quality, quantity, anything about my work. They didn't like that I came to work at 8:30 instead of 8 o'clock. My oldest child was less than five years. I had a baby essentially every year and it was very hard to make everything work out for an 8 am arrival. The people who were judging me were all bachelors.

Vera Rubin, astronomer

From a very early age, Vera Rubin (1928–2016) was interested in the stars. She graduated from Vassar College, where Maria Mitchell, the first professor of astronomy worked in the late nineteenth century. Rubin became famous for finding evidence for the first time for the existence of dark matter; at a time when no one wanted to believe this. Eventually, she became a well-known and well-respected astronomer, who received, among others, the US National Medal of Science (1993) and the Gold Medal of the Royal Astronomical Society (London, 1996), the second woman so distinguished after Caroline Herschel in 1828.

Vera had a supportive husband (also a scientist) and they had four children. Nothing proves better how Vera and her husband managed to bring them up than the fact that all their four children have become scientists. Comments from her children augmented Vera's autobiography in *Annual Review of Astronomy and Astrophysics* and give a hint about their extraordinary family [27]:

Dave: "One evening, when I was a child about ten years old, my mother told me that she knew something about astronomy that no one else knew. To this day, I remember thinking that this was extraordinary. …. what my mom alone then knew was the beginning of the story of dark matter."

Judy: "We saw our parents working hard and having fun being scientists, but none of us knew at the time that we would all choose to follow their lead. … I feel truly blessed and deeply grateful to be able to say, 'Vera Rubin is my mother'."

Karl: "I'm not sure when I realized that growing up in a household headed by two scientists was unusual. As a young child, I just assumed that almost all adults were scientists and that astronomy was a job for women. …. There was never ever pressure to become a scientist, but it did seem like the natural thing to do. …I've learned that … having parents, who understand and encourage such a life is an advantage most of my colleagues didn't have."

Allan: "I think it's no coincidence that the four children all ended up doing science. A pervasive early memory of mine is of my mother and father with their work spread out along the very long dining room table, … At some point I grew old enough to realize that if what they really wanted to do after dinner was the same thing they did all day at work, then they must have pretty good jobs."

Vera summarized for me her *ars poetica*: "My greatest pleasure has come from combining the roles wife/parent/astronomer. None would have given as much joy alone. … Cold dark nights at a telescope have been among the greatest treasures of my life [28]."

Final thoughts

Currently, we are witnessing an increasing attention to women's role in science. Alas, the number of women at the higher levels of academia has remained low. The principal challenge for most women is accomplishing a double career of doing science and having a family life. Administrative measures are being introduced at more and more places to ease the struggle of young women in overcoming inherent barriers to embark on and sustain a successful career in science, but it is a slow process. There is also need for inspiration. There are plenty of role models of women scientists whose example is the best argument for ambitious and gifted

young women to choose science for their profession. My aim with this paper was to present such role models and by doing so provide encouragement for budding scientists.

Article note: A special collection of invited papers by recipients of the IUPAC Distinguished Women in Chemistry and Chemical Engineering Awards.

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