

A Comparative Study of Nobel Prize Winners in Chemistry and Physics Over a Century Focusing on Gender and Age

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ABSTRACT

The Nobel Prize is considered as one of the most prestigious awards universally. In this study, we analyzed gender and age at the time of award in two areas of physical science, chemistry and physics. Based on data from 419 laureates, we were looking for trends over the time period of one hundred twenty-three years. We divided this period in two parts: the twentieth century and twenty-first century. Then we compared data for Chemistry and Physics Nobel Prize groups looking for similarities and differences within each field and then compared one field to another. We primarily focused on three parameters: (i) representation of women among winners, (ii) average age of all laureates and (iii) ages of men and women award winners. Our analysis indicates that women in both areas are representing a small proportion of all Chemistry and Physics Nobel Prize winners. However, there is an upward trend in women representation from the past to present century in both fields. Overall “aging” appears to be not gender-specific for both Chemistry and Physics Nobel Prize laureates. Demographic data analysis revealed an interesting fact: on average, both chemistry and physics women laureates are younger than men. Alfred Nobel in his will of 1895 designated the prize to “those who during the preceding year have conferred the greatest benefit to humankind.” Acknowledging the global significance of a Nobel Prize, we hope that our findings will motivate more girls and women to pursue science leading to a smaller gender gap in chemistry and physics.

Introduction

The Nobel Prize was awarded for the first time in 1901. Renowned Swedish scientist and businessman Alfred Nobel established the prize in his will to be granted on the annual basis for major achievements in physics, chemistry, physiology or medicine, literature and peace. Later in 1968, a memorial prize in economic sciences was added. The most recent, 2023 Nobel Prize amount was 10 million Swedish kronor, equivalent to more than one million U. S. Dollars (nobelprize.org).

In our previous work, we analyzed women’s representation in the Chemistry Nobel Prize (Lyubartseva & Arthur, 2022) from 1901 up to 2020. With Carolyn Bertozzi winning the Nobel Prize in Chemistry in 2022, we updated the number of women and total number of laureates in the current study. Still, in over one-hundred-twenty-year-long period, only eight women were awarded the Nobel Prize in Chemistry out of one hundred ninety-four laureates. Out of these eight women awardees, five won Nobel Prize in Chemistry in the twenty-first century over the time period of thirteen years: most recently, Carolyn Bertozzi in 2022 for the development of bioorthogonal reactions, Emmanuelle Marie Charpentier and Jennifer Doudna in 2020 for the development of CRISPR/Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats) genetic scissors biotechnology, Frances Arnold for the bioengineering work on directed evolution of enzymes and Ada Yonath in 2009 for her protein crystallographic studies of the structure and function of the ribosome. Three women were awarded the Nobel Prize in Chemistry during the twentieth century: Dorothy Crowfoot Hodgkin in 1964 for solving the atomic structure of molecules such as penicillin and insulin using X-ray crystallography, Irène Joliot-Curie in 1935 for the synthesis of new 'designer' radioactive elements and Marie

Curie in 1911 for the discovery of the radium and polonium. Chemistry and physics are two sisters of physical science and we were interested to analyze and compare women's representation in these two closely related fields in the current study.

Our age analysis of the Chemistry Nobel Prize Laureates revealed that over time the age of laureates increases regardless of gender from the twentieth to the twenty first century (Lyubartseva & Arthur, 2022). However, women appear to win the prize at a younger age compared to men on average. In the present work with the inclusion of updated data for the Chemistry Nobel Prize laureates, we aimed to look for similarities and differences in women's representation and overall age trends between the Chemistry and Physics Nobel Prize laureates.

Results

Women's Representation in the Pool of Chemistry Nobel Prize Laureates

We surveyed 194 Nobel Prize winners in Chemistry from 1901 to 2023 as described on the website of Nobel Prize (nobelprize.org). As of today, women currently represent 4.1% of all Nobel Prizes in Chemistry.

The percentage of women Chemistry Nobel Prize winners has increased fourfold in the current century compared to the previous one: from three women laureates out of one hundred thirty-two in the twentieth century to five women laureates out of sixty-two in the twenty-first century.

Table 1. Number of men and women Chemistry Nobel Prize laureates in 1900's and 2000's based on data from 1901 to 2023.

Number of Laureates in a Time Period	1900's	2000's	1900's + 2000's
Number of Men Chemistry Nobel Laureates	129	57	186
Number of Women Chemistry Nobel Laureates	3	5	8
Total Number Chemistry Nobel Laureates	132	62	194

Women's Representation in the Pool of Physics Nobel Prize Laureates

We surveyed 225 Nobel Prize winners in Physics from 1901 to 2023 (nobelprize.org). Based on the data analysis, women currently represent 2.2% of all Physics Nobel Prize laureates.

The percentage of women Physics Nobel Prize winners has increased by about four times in this century compared to the past one: from two women winners out of one hundred sixty in the twentieth century to three women winners out of sixty-five in the twenty-first century.

Table 2. Number of men and women Physics Nobel Prize laureates in 1900's and 2000's based on data from 1901 to 2023.

Number of Laureates in a Time Period	1900's	2000's	1900's + 2000's
Number of Men Physics Nobel Laureates	158	62	220
Number of Women Physics Nobel Laureates	2	3	5
Total Number Physics Nobel Laureates	160	65	225

Age of Chemistry Nobel Prize Laureates

From 1901 to 2023, the age of the Chemistry Nobel Prize winners at the time of the award varies from 35 years to 97 years. The youngest was 35-year-old laureate Frédéric Joliot, who received the Chemistry Prize in 1935 together with his wife Irène Joliot-Curie "in recognition of their synthesis of new radioactive elements." The oldest laureate was John Goodenough, who was a 97-year-old when he won the award in 2019 "for the development of lithium-ion batteries."

Based on data in table 3 below for the whole period from 1901 to 2023, women who won the Nobel Prize in Chemistry are younger than men with an age difference of five years, on average.

From the last to the current century, the average age of men Nobel Prize Laureates in Chemistry increased by 16% from 1900's to 2000's. For women laureates the percentage increase of age is about two times more than it is for men, 31%.

Table 3. Average age of Chemistry Nobel Prize laureates at the time of the award based on data from 1901 to 2023.

Number of Laureates vs. Time Period	1900's	2000's	1900's + 2000's
Average Age of Men Chemistry Nobel Laureates	55	64	58
Average Age of Women Chemistry Nobel Laureates	45	59	53
Average Age of Chemistry Nobel Laureates	55	64	58

Age of Physics Nobel Prize Laureates

The age of the Nobel Prize in Physics winners ranges from a 25-year-old Lawrence Bragg, who was awarded the Nobel Prize together with his father Sir William Henry Bragg "for their services in the analysis of crystal structure by means of X-rays" in 1915, to Arthur Ashkin who was a 96-year-old when he was received the Nobel Prize "for the optical tweezers and their application to biological systems," together with Gérard Mourou and Donna Strickland "for their method of generating high-intensity, ultra-short optical pulses" in 2018.

When we divided the Physics Nobel Prize laureates in two groups based on gender, we noticed that on average women laureates are younger than men with an average age difference of two years.

When comparing the age of laureates in two centuries, the average age of men Nobel Prize in Physics laureates age increases by 35% from 1900's to 2000's. However, for women laureates the percentage of the age increase is slightly less than it is for men, 28%.

Table 4. Average age of Physics Nobel Prize laureates at the time of the award based on data from 1901 to 2023.

Number of Laureates vs. Time Period	1900's	2000's	1900's + 2000's
Average Age of Men Physics Nobel Laureates	52	70	57
Average Age of Women Physics Nobel Laureates	47	60	55
Average Age of Physics Nobel Laureates	52	69	57

Discussion

Women Representation in the Pools of Chemistry and Physics Nobel Prize Laureates

From the records of the Chemistry Nobel Prize award up to 2023, eight women were laureates, representing about four percent of all Nobel Prizes in chemistry (nobelprize.org). However, our data analysis indicated that the representation of women Nobel Prize winners in Chemistry is following an upward trend as from 2% in 1900's it increased to 8% in 2000's.

The total number of women Nobel Prize winners in physics is about one and a half times smaller compared to chemistry. From 1901 to 2023, five women had been awarded a Nobel prize in Physics. The most recent 2023 Nobel Prize laureate in Physics, atomic physicist Anne L'Huillier was awarded the prize "for experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter." Three years back in 2020, astrophysicist Andrea Ghez received the Nobel Prize in Physics "for the discovery of a supermassive compact object at the centre of our galaxy." Optical physicist, Donna Strickland was a winner of the Nobel Prize in Physics in 2018 for pioneering the laser physics research. In the twentieth century, theoretical physicist Maria Goeppert Mayer won the Nobel Prize in Physics in 1963 in a recognition of her discovery of a shell model of the atomic nucleus following Marie Curie in 1903 after a sixty-year break for women being awarded the Nobel Prize in Physics.

Despite of a small number (about two percent of all Nobel Prize laureates in Physics are women), the representation of women is increasing, in a magnitude similar to the Chemistry Nobel Prize, from 1.3% in 1900's to 4.8% in 2000's (nobelprize.org).

A growing body of literature is dedicated to possible reasons for the small numbers of women in STEM fields. We discussed the most commonly mentioned reasons in our previous study, including gender-related stereotypes and bias including but not limited to alleged cognitive ability and field-specific myths, lifestyle values and family-work balance, occupational interests and preferences and lack of support and mentorship (Lyubartseva & Arthur, 2022). There is no scientific evidence supporting a common myth that women's cognitive abilities are lower compared to men's in science and mathematics, based on behavioral and brain studies (Halpern et al., 2007). As Halpern et al. concluded in their report, there is no simple yes or no answer to the question whose brain is "more wired" for STEM fields either. For example, women tend to have stronger verbal abilities, especially pronounced in

writing. In science fields such as chemistry and physics, communication and reporting are critical starting from undergraduate student laboratory reports to highly competitive grant writing in research institutions. However, on average men outperform women on most measures of visuo-spatial abilities, which could be useful during scientific experimentation. Based on presented facts, it appears that women and men would complement each other in various areas of scientific research judging by their intellectual strengths (Charlesworth & Banaji, 2019) and therefore, could benefit from a collaboration.

Numerous studies indicate that upbringing and sociocultural factors play a crucial role in women's underrepresentation in math-related and science fields. 2022 Nobel Prize in Chemistry winner, Carolyn Bertozzi, mentioned her "privileged" upbringing as a daughter of MIT physics professor where she had no limitation of her choice to pursue a career in science from the very early age (nobelprize.org).

Some reports (Ceci, 2018; Ceci & Williams, 2015) note that prejudice and gender discrimination are becoming part of the history. However, vast majority of modern studies reveal that gender stereotypes in science still persist, perhaps in a different, less open form now compared to the past (Wang & Degol, 2017), but nevertheless they affect girls' and women's motivation to start or continue career in science leading to an existing gender gap (Bureau, 2021; Charlesworth & Banaji, 2019; Lerman et al., 2022; Llorens et al., 2021; Meho, 2022; Rørstad & Aksnes, 2015; Ross et al., 2022; Roy et al., 2020).

The most renown scientists were awarded the Nobel Prize in Chemistry and Physics for their pathbreaking discoveries in these fields. Out of numerous factors leading to recognition of major discovery by a scientific community, the publication rate is one of the easily measurable quantities. Large scale study of 12,400 Norwegian university researchers indicated that academic position is more important than age and gender for publication rate; for example, professors have higher publication rate compared to associate professors (Rørstad & Aksnes, 2015). In addition, the study shows that women researchers are found to publish less compared to their men counterparts. The report by Ross and others published in *Nature* in 2022 shows that women in science are less likely to be named authors on any document in various science fields and at all career stages, they are much less likely to be named on high-impact articles leading to the conclusion that a gender gap may result from lesser recognition of women's achievements compared to men's achievements in science (Ross et al., 2022). These findings are consistent with the recent MIT report, which points at the gender gap among highly cited researchers in chemistry and physics and other natural sciences, where women represent only 4 to 7% of all highly cited researchers although they make up 25 to 35% of the fields' authorship (Meho, 2022).

Our data analysis of the Nobel Prize in science (chemistry and physics) in regards to gender of laureates is consistent with previously published reports described above indicating historical and existing gender gap. The numbers of women Chemistry and Physics Nobel Prize laureates are still significantly lower than men, however, the upward trend for women's representation in both fields is inspiring for women and girls pursuing these physical science fields.

The Age Analysis of Chemistry and Physics Nobel Prize Laureates

For the age study of the Nobel Prize laureates in Chemistry and Physics we looked at the age at the year of the award was won by each laureate and obtained an average age of the Nobel Prize awardees for each field. Then we compared an average age in 1900's winners' pool and 2000's winners' pool for each area separately (chemistry and physics) following comparisons between areas.

In the Chemistry and Physics Nobel Prize winners combined, the age of laureates ranges from a twenty-five year old Lawrence Bragg, who is also the youngest Nobel Prize winner in all science fields, to a ninety-seven-year-old John Goodenough who is currently holding a record as the oldest Laureate among all areas of Nobel Prize. During the period of the Nobel Prize existence, the average ages of the Nobel Prize winning in both areas are very similar for these two fields of science: 58 years in chemistry and 57 years in physics. Both Chemistry and Physics Nobel Prize winners "age" from the twentieth to the twenty first century. For chemistry laureates, the average age difference is

nine years. For physics laureates, the average “aging” is more prominent, with a difference of seventeen years from 1900’s to 2000’s. Observed aging of the Nobel Prize winners is consistent with aging of American and European scientists and science professors due to multiple reasons such as a decline in the retirement rate of older scientists after the elimination of mandatory retirement in the U.S. universities in 1994 and aging of the baby boom generation (Blau & Weinberg, 2017; Ghaffarzagdegan & Xu, 2018).

When comparing an average age of men to average age of women Nobel Prize winners, the age difference is five years for chemistry and two years for physics, with women being younger than men at the time of the award. Considering a small number of women compared to men in both chemistry and physics pools, it may be preliminary to present this fact as an established trend in age of Nobel Prize laureates in regards to gender of winners. However, it is an interesting finding consistent across Nobel Prize awards in two fields of physical science. As mentioned in our previously published report, we expected to find the opposite age difference when we analyzed ages of Chemistry Nobel Prize winners and our initial hypothesis was proven incorrect (Lyubartseva & Arthur, 2022). On contrary, based on one-hundred and twenty-three-year long history of the Nobel Prize, women obtain world-wide recognition in both chemistry and physics at a younger age compared to men on average. One possible explanation of this phenomenon could be found when closely analyzing ages of women in Curie family. The youngest woman who won the Nobel Prize in science is Marie Curie, the Physics Nobel Prize at thirty-six years of age. She is closely followed by her daughter Irène Joliot-Curie, thirty-eight-year-old at the time of the award, the Chemistry Nobel Prize. Marie Curie is the only Nobel Prize laureate among all men and women who won Nobel prizes in two science areas, she was awarded her second Nobel Prize at the age of forty-four in Chemistry. Notably, mother and daughter Curie’s relatively young ages at the time of their awards possibly explains the age difference between women and men groups in 1900’s. However, the persistence of the age difference between men’s and women’s pools in 2000’s could be the indication of a trend.

Finally, the “aging” of the Nobel Prize winners from the twentieth to twenty-first century appear to be not gender specific and reveals itself in various proportion when comparing men and women winners in chemistry and physics. Men Nobel Prize laureates in Chemistry are older by 16% in this century compared to the previous one. Women laureates in Chemistry are “aging” more drastically compared to men: the average age increased by 31%. The opposite was observed during age analysis of Physics Nobel Prize winners. For men, the average age increased by 35% from 1900’s to 2000’s. For women laureates, the percentage of age increase is smaller, 28%. In conclusion, the Nobel Prize in Chemistry and Physics winners are getting older with time, the finding which is consistent with increased life expectancy (Kirkwood, 2017), longer years of formal education (Gakidou et al., 2010) and extended academic carriers in the twenty-first century compared to the twentieth century (Blau & Weinberg, 2017).

Conclusion

The year of 2018 was a remarkable year in the history of the Nobel Prize in science, because two women, Donna Strickland and Francis Arnold won their awards in chemistry and physics correspondingly. Francis Arnold in her interview with Guardian remarked: “I predict this is the beginning of a steady stream” in regards to women’s recognition by Nobel Prize in chemistry and physics (“Frances Arnold’s Thoughts on Winning the Nobel Prize,” 2019). Based on our study of 419 Nobel Prize winners in these fields, the share of women scientists among Nobel Prize laureates although still small, is increasing in the twenty-first century compared to the twentieth century. We also observed that regardless of gender, the Nobel Prize winners in Chemistry and Physics are “aging” as the average age at the time of the award is more advanced in the current century in comparison to the average age in the previous century. Notably, throughout the whole period of a Nobel Prize award, both chemistry and physics women laureates are younger compared to men, on average. We hope that our findings contribute to understanding and addressing a gender gap in chemistry and physics and serve as a motivation for girls and women to choose science.

Limitations

Due to a relatively small number of women who won the Nobel Prize in Chemistry and Physics compared to men up to date, classical statistical analysis was not possible in the current study.

Acknowledgments

Ganna Lyubartseva acknowledges her former research students: Hee Kyung Jeon, Morgan Coleman, Shamiso Nsongoni, Alex Davis, Cheyenne Arthur and Jared Hickson for their active participation, her colleagues at the College of Science and Engineering and Department of Biochemistry and Chemistry for their continuous support and encouragement and Dr. Svetlana Liubartseva for the inspiration.

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