

STATISTICAL ANALYSIS OF NOBEL PRIZES IN PHYSICS: FROM ITS INCEPTION TILL DATE

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(Received July 10, 2018; in final form September 27, 2018)

Nobel prizes in various subjects, including physical sciences, were initiated at the very early juncture of the twentieth century, were awarded to a person with a significant contribution and groundbreaking research in the respective field. It is the most prestigious award known at the international level about which the society is inquisitive at large. The present article presents an analysis of about 204 Nobel laureates in Physical Science from the inception of this prize till date, which may provide an insight into the developmental stages of the subject. The analysis has diversified aspects like research fields in Physics, the age of the laureates at which the inventions were carried out, the universities where they belong to, migration of the researchers and their gender. The analysis also includes the areas where the prizes were expected but were not awarded, though the particular research had a significant impact on the respective field.

Key words: physical science, Nobel laureates, statistical analysis, research fields.

DOI: <https://doi.org/10.30970/jps.22.3002>

PACS number(s): 03.65.–w

I. INTRODUCTION

The astonishing and outstanding research from Chemistry, Physics, Medical science, Literature and Economics is being recognized with the prestigious Nobel Prize every year. The prizes are given in the memory of Swedish scientist Alfred Nobel, since 10th Dec 1901, five years after his death. It has been acknowledged as the most precious and significant award and attracts a great inquisitiveness among researchers as well as the society.

The Royal Swedish Academy of Sciences announces the prize winners in October and they are honored on 10th of December; every year on the death anniversary of Alfred Nobel. The selection process is governed by the Nobel Foundation with a committee of a few members associated with the Royal Swedish Academy, following the selection criteria as per Alfred Nobel's will. This award is conferred on the person for his/her revolutionary research and the invention that improves technological developments for human beings [1]. The Prize has received a mammoth international fame for the results obtained by the winners in their particular core areas. Initially, the prize was awarded only to the researchers in Physics, Chemistry and Medicine or Physiology. However, prizes for Literature and Peace were started later [2]. The prize consists of a medal, a memento, a diploma from the Swedish Academy and a particular monetary reward which varies every year [3–4]. The prize winners have always played a key role in making policies of their own countries, which in turn influences areas of science and technology of that region. Common people are always eager to know about the laureates and their field of research and their country as well [5–6].

A variety of databases are always analyzed to interpret

the data, dig out the association within the database entries, predict further trends, determine loop holes or even to formulate a matrix that can be used to outline a strategy. In the context of the analysis of Nobel prizes, there are reports on the analysis of this prestigious award based on a variety of criteria.

Weijia Zhang and Robert Fuller in their article “Nobel prize winners in physics from 1901 to 1990: Simple statistics for physics teachers” [1] discussed the demographic database for 139 Nobel prize winners in physics from 1901 to 1990. Along with the statistical analysis based on various criteria, this article has pointed out some significant aspects of physics education which underline the need for collaborative work, conducive environment and “do-it-yourself” approach by the family of the laureates, immense interest in science developed right in childhood, etc. which themselves describe why this “special population” could achieve the Everest of success. Yves Gingras and Matthew L. Wallace have presented a bibliometric analysis of Nominees and Winners of the Chemistry and Physics Prizes (1901–2007) wherein they observed that the Prize is awarded at the peak of the winners’ careers, despite a brief Halo Effect observable in the years following the attribution of the Prize [7]. They further mention that there is a rapid decline in the predictive power of bibliometric data due to a variety of reasons. Hideyuki Doi *et al.* used a statistical technique, hierarchical partitioning to simultaneously explore and compare the influences of a large range of explanatory factors concerning the crucial predictors of a country’s number of Nobel awards [8]. In a paper on collaborative research of Nobel laureates, Wagner *et al.* report that the number of papers produced by the laureates is smaller but they have higher average citations, they have more “sole au-



thor” publications and have a network among the “star scientists” [9]. In the article “A preliminary analysis of the Nobel laureates”, Cindy Wang has discussed various aspects of the prize and the prize winners that include the number of Nobel prizes given, the life span of the laureates, the universities from where they graduated, the criterion for the award of the prize, etc. [10]. Salvino A. Salvggio in his “R-blog” has also presented an analysis of data on Nobel laureates. He has presented this analysis considering the categories in which the prizes are awarded, the “sharing” aspect of the prize; the age – gender – countries – migration of the laureates, etc. [11]. These analyses help to understand various facets of the prestigious award.

For the last few decades, numerous articles analyzing Nobel laureates have been published [12] but they have a limited motive or confinement and have an inadequate detailed statistical analysis of the prize recipients in Physics [13–15]. Therefore, we present a systematic analytical overview of the prize winners, particularly in Physics, and present a detailed analysis of the demographic database for 204 Nobel Prize winners in Physics from 1901 till date. A special highlight is given to their award-winning areas. Our analysis consists of a databank of 204 winners with respect to the field of research, the year in which the award-winning research activity was carried out, the actual award-winning year, the origin of the laureate, their institution, the age at the time of the research, the interval of time between the invention and the awarding year, aspects like whether honored individually or in the shared manner, etc. The recipients that migrated from their motherland were emphasized during the analysis, as they constitute a significant number. The dominance of the USA after 1950s in the prize list along with a downfall in the number for Britain and other European countries is also highlighted in the analysis [16]. The purpose of this article is to visualize an analytical picture of Nobel laureates and their distinguished achievements. In a nutshell, the thrust for this work is to evaluate a detailed bibliographic data about the recipients in different analytical aspects.

II. METHODS

Details on the prizes given in Physical science were collected from the official website of the Nobel Foundation for the entire period of the award, that is, from 1901 till 2017 [17]. This also included the lectures of the laureates, the details of the prize-winning research and its impact on the respective field. Articles published in well-known journals, papers written by the recipients were also examined. The databank so formed was then classified as per various aspects, like the field of research, the age of the inventor at the invention and the age when he/she was honored, gender, the origin of the laureate and the organization where the work was carried out. The analysis also includes the areas where prizes were expected but not awarded, though the particular research had a momentous impact on the respective field. The fact that

prizes were not awarded during the years 1916, 1931, 1934, 1940 to 1942 due to the World Wars was also considered.

III. RESULTS AND ANALYSIS

A. Recipients’ Gender

The statistics on the gender of the award winners is presented in Figure 1. It shows that male recipients have subjugated the field of physical sciences. Out of 204 winners, only two lady researchers, that is, Marie Curie (1903) from Poland for her landmark work on the radiation phenomenon and Maria Goeppert-Mayer (1963) from the USA for discoveries concerning nuclear shell structure, were honored. It took almost sixty years for a lady scientist after Curie to be awarded with such a prestigious prize. Marie Curie was a rarest scientist to get the prize twice, and that too, in two different subjects.

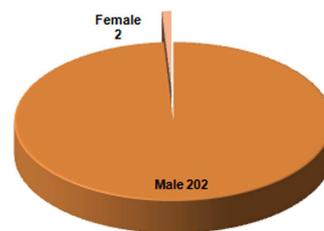


Fig. 1. Gender wise classification of awardees.

The reason for such a very small number of lady researchers winning the Nobel can be understood from the then socio-economic conditions. During the 20th century, the freedom of a “girl student” was much restricted owing to religious faith, insecurity, economic / war like conditions, etc. Further, these reasons were common to both developed as well as underdeveloped countries. This could have led to a high dropout ratio of girls, mostly at the school level itself. A very small percentage of them, who could complete their graduation, were able to proceed with research activities, provided, they could get better financial support from their family or the society. Thus, whatever may have been the exact situation for a particular girl student, the end result was a fractional female-to-male ratio in the achievers. There may be some female dignitaries who might have achieved other high-profile positions / awards; however, it is beyond the scope of the present analysis.

B. Distribution of the laureates by Nation

Figure 2 illustrates the analysis based on the native country of the prize winners. It considers the homeland of the recipients, though some of them had migrated to other countries when they were honored; for example, Philipp Eduard Anton Lenard is considered to be from Austria as he had Austria-Hungary citizenship while he

was awarded Nobel in 1905, though he migrated to Germany after 1907. It is clear from the data that the USA has dominated the scientific world, receiving a large number of prizes, or about 37% of the total number. It is observed that in the pre-world war (WW) period, Germany, UK and France bagged significant number of the prizes. In the post-war scenario, the European countries witnessed a crunch in their economies whereas the research institutes in the USA were encouraged with towering funds, the result of which was reflected in major discoveries and inventions leading to more of Nobel Prizes been given to the USA.

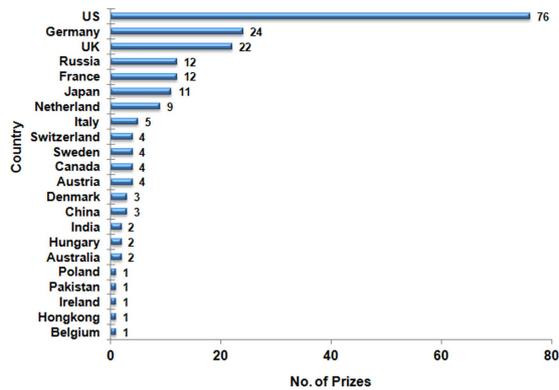


Fig. 2. Country wise classification of award winners.

Though the USA has a limited historical background, it could have a greater number of Nobel laureates. This can be well understood from the scientific temperament of the society in assorted regions of the world. Some of the developed countries, along with the USA, realized the significance of scientific education and research in the pre-WW world. This led to encouragement like extensive government funding for research, social recognition to experimental verification, and development of curriculums to inculcate logical reasoning in the students. However, in the post-war circumstances, the fall of economy eroded this environment. Therefore, a dominant player in WW, the USA, had a distinct policy to bestow enormous funding for applied research on eminent scientists and provide a conducive habitat. These efforts have rewarded the USA not only in terms of the significant number of the Nobel laureates but the country is now known as a hub of intellectuals with an established scientific culture.

C. The age of the laureates

Figure 3 illustrates the analytical view considering the age factor when scientists were honored with the prize. Almost 27% of the prize holders were from the age group of 41 to 50, i.e. at the mid of their career. Also, 25% of the prize-holders were in their 50s. Only Sir William Lawrence Bragg from the UK got the prize when he was 25 years old and shared it with his father Sir William Henry Bragg in the year 1915 for developing X-ray crystallography technique. Thus, 28 recipients were

most lucky as they were honored when they were at the initial stage of their careers, that is, in their 30s; which must have inspired them to visualize their future plans in a more innovative way. The data also shows that there are 9 Nobel laureates who received the prize when they were in their 80s; to name a few, Kapitsa (84), Raymond Davis (88), Ginzburg (87), Yoichiro Nambu (87), etc. A person aging more than 60 years is considered to be the most experienced one; about 34% scientists in this age group were awarded.

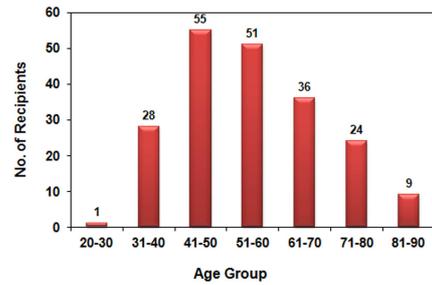


Fig. 3. Classification of recipients according to their age when the prize was conferred.

The histogram reveals that 106 laureates got the prizes while they were between 40 and 60 years old of their age, that is, in a time span when they were most experienced and enriched with knowledge and skills. However, it is important to note that the inventions were dated far prior to the time of the award. The main criteria for the Nobel Prize would reveal the mystery behind this. An invention is considered for Nobel only if the new theory is supported by appropriate experimental evidence (that was the prominent reason why Einstein could not get the Nobel for the theory of relativity). There were many logical concepts — theories with new innovative ideas — for example, in case of Astrophysics, fluid theory, gravitational waves, existence of elementary particles, etc., but they were difficult to establish on experimental grounds. Also, the then technology was inadequate to provide substantiation for these theories. In due course of time, developments in technological systems facilitated corroboration of the theories leading to the award of the Nobel to the astounding results. This elucidates the delay in awarding a Nobel Prize after an invention.

D. The age at the time of invention

Figure 4 shows the correlation between the number of the awards and the age of the recipients when they reported their groundbreaking work. This shows that almost 44% of the awardees had their innovations while they were in their 30s. This means that after the completion of their educational studies, they might have carried forward their pre-studies or interests in the respective fields leading to the fascinating results. Only three Nobel laureates, i.e. Karl Siegbahn (17 yrs) from Sweden for X-ray spectroscopy, Sir William Lawrence Bragg (20 yrs) from the UK for X-ray crystallography and Chandrashekar Subramanyam (20 yrs) from India for the

evolution of stars were the ones who established their results in their respective research fields before the age of 20 years. However, Ch. Subramanyam received the prize after 53 years after his findings. Only two recipients did the work when they were in their 60s, i.e. Isamu Akasaki from Japan for blue light and John Lewis Hall from the USA for Laser-based precision spectroscopy. Almost 23% of the prize winners did the prize-winning work when they were in their 20s. It is interesting to note that without any exception, all the prize-winning results were obtained before the age of 70. This implies that a revolutionary work needs zeal and knowledge and cannot completely be ascribed to the experience of the inventor.

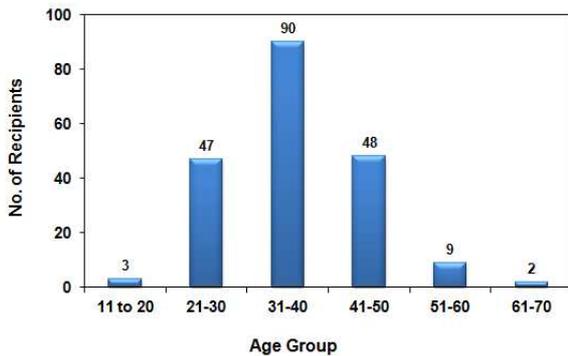


Fig. 4. Classification according the age of the awardees at the time of invention.

There are 140 Nobel Prize winners (~ 69%) who have reported their invention before their 40s. This can be explained by considering the human psychology. Along with the accretion of skills, a person, perhaps a researcher develops a typical line of thought based on his experiences; but turns to be repugnant to new ideas and follows a specific path. Thus, the younger age might be in favour of contemporary ideas; which is reflected in a larger number of prize-winning inventions at an early age of the inventors. There is another outlook on this proposition. Some of the Nobel laureates got an opportunity to build their careers in their respective interesting fields just after the completion of their formal education and continued their prior work and were fortunate to receive conducive work culture and guidance for the same. The situation might not be favorable while one starts the work at a later stage of life. This notion is supported by the mere number of award winners who came up with innovations during their autumn years.

E. Time difference between the invention and the award

Figure 5 shows the timeline statistics on the point of invention and the instance when the award was declared. About 27% of the recipients were acknowledged with the prize within 10 years of the invention which is obvious. Also, 34% of the awardees got their prize within 11 to 20 years of the invention. However, there are a few (6%) unlucky conferees who had to wait for over

40 to 50 years. Also, there are three winners who got their prize more than 50 years after the invention. Ch. Subramanyam, Ernst Ruska and Vitaly L. Ginzburg got the prize 53 years after the invention. It is also interesting to note that, only four laureates, namely Chen Ning Yang, Tsung-Dao Lee both for particle Physics and J. Georg Bednorz, K. Alexander Müller for superconductivity, were the luckiest to be honored within one year of their innovative results. The analysis shows that there are a few pioneers in the all-time history of Physics, who had to wait for a long time to be honored by the Nobel Foundation Committee; to mention a few of them, Max Plank (18 years), Einstein (16 years), Neils Bohr (9 years), Otto Stern (21 years), Max Born (29 years), Pauli (20 years).

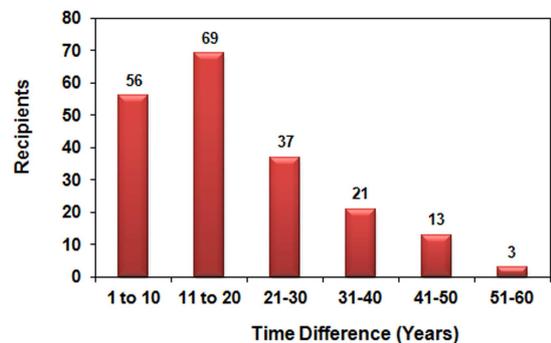


Fig. 5. Number of recipients against the time difference between invention and the award.

F. Individual/shared nature of the prize

Figure 6 shows that only 23% of the recipients were awarded individually and almost 77% had to share the prize. Among the individual prize-winners, most of them got the prize before 1950s and were primarily Europeans. The scenario changed in the post-WW era, where a “shared” prize conception is found to be predominant, the USA grabbed about 39% of the prizes, including the migrants to the USA.

The pie chart shows that only 23% of the winners received the prize independently. Most of these winners belong to the pre-WW epoch. As mentioned earlier, before the world wars, Europeans had the whip hand in the field of research. Though the number of European research institutes was limited, they were benefited with giant funds. Also, a limited number of researchers were working in new branches of physical sciences, namely, quantum mechanics, nuclear physics and astrophysics. A country-wise glance at the award-winners prior to 1950s show that many countries, except Germany and Britain, had hardly a couple of prize winners. The USA was silent in this field. In the post-WW economic framework, financial resources for European research institutions were cut down significantly, which resulted in a massive migration of experienced and visionary researchers to the USA. These erudite migrants adopted a fascinating policy to have multiple groups of people (within the USA itself) to work on the same project at the same time. This

led to similar mesmerizing results been reported simultaneously by more than one inventor; with the benefit that the results were cross-confirmed instantly. This forced the Nobel Committee to nominate a group of brilliant minds for the prize. The data reveals that most of the shared prizes were awarded to scientists from the USA (80 laureates). Till date, the same trend has continued and there are hardly any scientists in recent decades who have been awarded individually, at least not in physical sciences.

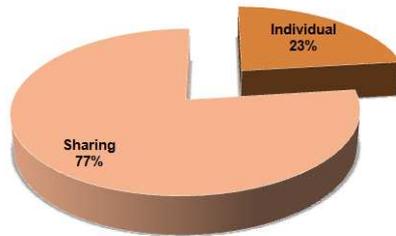


Fig. 6. Distribution of number of recipients according to individual or shared nature of the prize.

G. Individual sharing as per the countries

It can be inferred from Figure 7 that Germany, the UK and the USA have dominance with more than 8 individual awards. In a sharing form, the USA is in a commanding position, having received 80 prizes, which turns out to be 39% of all. Asian countries are far behind in individual awards; both in the pre- and post-WW era, with an exception of Japan, which has received one individual award and 8 in the sharing mode. Roentgen, Rayleigh, Lenard, Thomson, Michelson, van der Waals, Wien, Laue, Einstein, Bohr, etc. are the legends who received the Nobel individually.

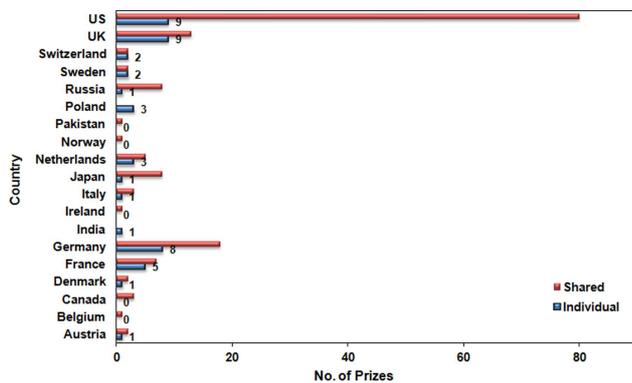


Fig. 7. Country wise distribution of individual or shared nature of the prize.

H. Distribution as per research field

The bifurcation of Physical Sciences has its origin in the seminal Nobel results. Before 1900, there were hardly

a few research areas wherein people were working: Classical Mechanics, Thermodynamics, Optics, Electromagnetism, etc. Many fields evolved in the 20th century. Almost 37% of the awards were given to Nuclear Physics and 17% to the inventions in Material Sciences, whereas merely 10% of the awards were given to Quantum Mechanics (much of those were between 1901 and 1930). This is a clear indication of building the research areas according to the needs of the society. The least developed areas were astrophysics (7%) and superconductivity (5%), which got enough funding and fame from the society, but less recognition through the Nobel. These facts are presented graphically in Figure 8.

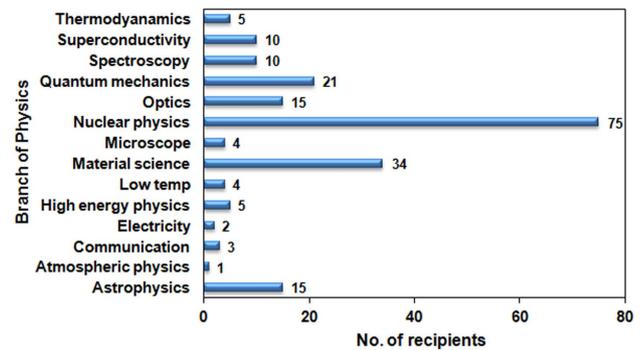


Fig. 8. Branch wise distribution of the prize.

The most popular branch in physical sciences is nuclear physics. Most of the countries, whether developed or economically backward, are able to carry out research with technologies pioneered by leading institutes. This branch evolved from radioactivity theories developed by a group of people in the early period of the 20th century. The knowledge pool was quite advanced to invent new elementary particles, nuclear reactors, etc. Nuclear weapon was a vivid product of this branch and was aggressively funded for further research by governments of numerous countries. Organizations like CERN were established for a better collaborative research on nuclear theories, resulting in a great number of Nobel Prizes in Nuclear Physics.

I. Analysis of the migration

Figures 9,a-c portray the percentage of Nobel laureates classified according to the migration of the researchers. There are numerous reasons for which people migrated from their original countries. Almost 14% of the laureates got the prize after migration, in which the USA has a share of 59%. This can be attributed to the nourishing policies of the USA government towards research and development. The USA attracted most of the people from Asian and European countries. It is also interesting to note that there are 5 recipients who received the prize after their migration from the USA; however there is fair likelihood that the research culture in the USA might have had some contribution to the victory.

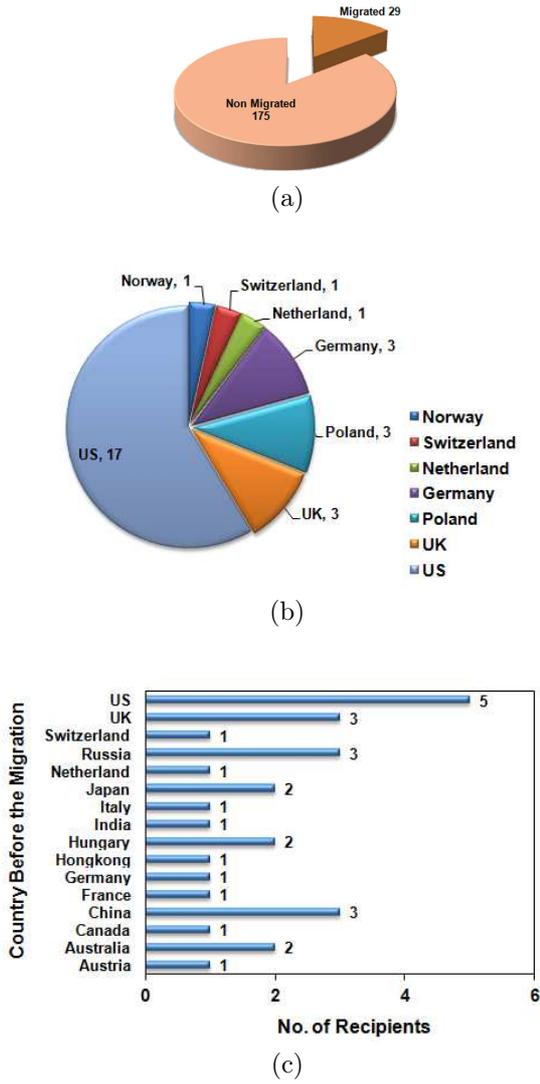


Fig. 9. (a) Classification of prize winners based on their migration status; (b) Classification of prize winners based on their country *after* the migration; (c) Classification of prize winners based on their country *before* the migration.

J. Analysis based on the birth year of the laureates

The data was analyzed according to the birth year of the prize-winners and is presented in Figure 10. The data shows that respectively 33% and 34% of the awardees were born in the time spans of 1901–1925 and 1926–1950. There are, in all, 27% of the awardees that were born prior to the commencement of the 20th century. An interesting result is that none of the post-1975 born scientists have received the prize in physical sciences so far. This shows that the average award winning age has increased to 40s, which was almost 30 in the 20th century. This also indicates that research or new avenues of research in Physics might have saturated the field after 1960s and could not impress the Nobel Committee.

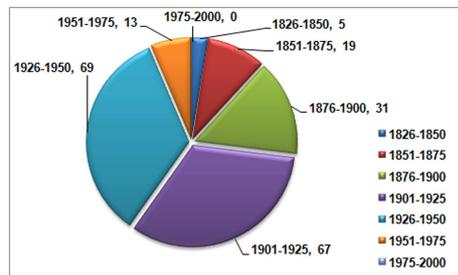


Fig. 10. Classification of prize winners based on their birth year.

The histogram shows that almost 136 people that were born between 1901 to 1950 received the Nobel Prize. This may be attributed to the advancements in the new theories like radioactivity, quantum physics, material science, etc. which were at the developmental stage in the first half of the 20th century. Leading research in these branches for the betterment of human life attracted immense interest among young brains who were perusing their school or undergraduate education at that time. These people got attracted to different areas and succeeded in further development of theories, which ultimately resulted in grabbing more Nobel prizes.

No.	Name of the Scientists	Country	Field of Research
1	Arnold Sommerfeld	Germany	Quantization rule
2	Gregor Wentzel / Hans Kramers / Léon Brillouin	Germany / Netherlands / France	WKB approximation method; weak potentials in quantum mechanics
3	David Hilbert	Germany	Defining infinite dimensions and development of a new mathematical theory
4	Marian Smoluchowski	Austria	Theory of Brownian motion; kinetic theory
5	Nikola Tesla	USA	Modern ac supply system
6	Thomas Edison	USA	Inventing Bulb
7	Murray Gell-Mann	USA	Got the Nobel once but expected to get again for discovery of Quark
8	Nikolai Bogoliubov	USSR	Theory of superfluidity and superconductivity
9	Satyendranath Bose	India	Bose–Einstein statistics
10	Jagadish Chandra Bose	India	Discovery of Radio
11	Fred Hoyle	Britain	Big Bang theory
12	Paul Ehrenfest	Austria–Netherlands	Theorem for the average motion of the wave packet

Table. Names of famous scientists not honored with the Nobel Prize.

Unlucky Intellectuals

There are many researchers in Physics who introduced pioneering concepts that have facilitated development of the theory and were supposed to be considered for the award. A few of them are listed in Table along with their field of research and the native country. However, they were unfortunate and could not be conferred a Nobel Prize.

Key findings

Here are some of the key highlights / outcomes of the analysis:

1. Female scientists constitute only 1% of the Nobel Prize winners, which shows dominance of males in the research area, at least in Physical Sciences.
2. European countries were far ahead in the research activities in pre-WW periods. But the USA showed a dominant nature in the post-1950s period, grabbing around 37% of all prizes.
3. Almost 66% of the prizes were awarded to the researchers before their 60s, i.e. before they were relieved of their activities.
4. About 69% of prize-winners carried out the prize-winning invention while they were in the age group of 20 to 40 years, which indicates that fresh brains always get new ideas.
5. After an invention, it takes the Nobel Committee much time to honor the intellectual personalities. Data shows that only 27% of Nobel laureates were awarded within 10 years from their invention and the rest of the people got recognition in a time from 10 to 60 years.
6. Max Plank, Albert Einstein, Niels Bohr, Max Born, who are believed to be the pillars of Physics, had to wait over an extensive period of time to get the Nobel Prize.
7. Wolfgang Pauli got the prize in 1945 when he was 45 years old and Dennis Gabor received the prize in 1971 at the age of 71.
8. The data reveal that only 27% of the laureates were awarded individually, most of them before the World War era. Asian countries are far behind in getting individual awards.
9. 14% of the laureates got the prize after migration; interestingly, 5 laureates migrated from the USA, where most of the researchers were attracted after the decline of the European economy in the post-WW period.
10. None of the post-1975 born researchers has ever received the prize so far in Physics.
11. 37% of the awards were given to Nuclear Physics, which is the most focused field in research areas.
12. Astrophysics (7%) and superconductivity (5%) were less recognized, though huge amounts of funds are invested in both areas, as compared to other fields.
13. Statistics show that the award-winning age of scientists seems to be around 40 years, which was just 30 a few decades ago.
14. Thomas Edison, Nicola Tesla, Fred Hoyle, S. N. Bose, Arnold Sommerfeld, etc. are the great names who had contributed through their pioneering work, but were most unlucky and were not honored by the prestigious award, though they left their impact on various branches of Physical science.

Acknowledgement: We thank Prof. R. S. Kawale, Sangamner College, Sangamner, Maharashtra, India for reviewing this article with fruitful suggestions and motivating us for the present work.

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**СТАТИСТИЧНИЙ АНАЛІЗ НОБЕЛІВСЬКИХ ПРЕМІЙ З ФІЗИКИ:
ВІД ЗАСНУВАННЯ ДО СЬОГОДНІ**

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Нобелівські премії з різних предметів, зокрема з фізичних наук, були засновані на початку ХХ століття. Їх присуджують ученим зі значним внеском та новаторськими дослідженнями у відповідній галузі. Це найпрестижніша нагорода, відома на міжнародному рівні, якою суспільство цікавиться загалом. У статті проаналізовано 204 лауреати Нобелівської премії з фізики від моменту створення цієї нагороди до сьогодні, що може бути корисним для ознайомлення з етапами розвитку фізичної науки. Аналіз має різноманітні аспекти: галузі досліджень, вік лауреатів, коли вони робили свої винаходи, університети, у яких вони працювали, міграція дослідників та їхня стаття. Аналіз також включає ті галузі, де нагороду очікували, але не присуджували, хоча конкретні дослідження мали значний вплив у них.