The Nobel Centennial 1901–2001

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Abstract: The year 2001 marks the 100th anniversary of the awarding of the first Nobel Prizes. This article briefly discusses the life and work of Alfred Bernhard Nobel, his will that instituted the prizes, the Nobel statutes, controversial recipients, neglected chemists, criticisms of the prizes, and the Nobel Centennial Celebrations. The prizes in chemistry and the international nature of the awards are emphasized.

Early every October, almost everyone looks forward expectantly to the announcement of the Nobel Prize recipients. This annual anticipation is so familiar that we seem to think that the prize has always been with us. Yet this *ne plus ultra* of achievement in "five fields of culture" (chemistry, physics, physiology or medicine, literature, and peace) will be only one hundred years old this year (Figure 1) [1]. A sixth field—economics—was added in 1969, but it is funded separately by the National Bank of Sweden (*Sveriges Riksbank*). The prizes bring the laureates handsome cash awards (about $1 million in 2000) [2], but the honor and distinction that they convey is treasured even more.

Nobel's Early Years

Alfred Bernhard Nobel (1833–1896, Figure 2) [3], chemist, inventor, entrepreneur, idealist, and philanthropist, is probably the world's best-known Swede—but indirectly rather than directly. While his prizes are world-renowned, this enigmatic visionary remains comparatively unknown to the public at large and even to some chemical educators.

Nobel was born on October 21, 1833, in Stockholm, Sweden, the third of the four surviving sons of Immanuel Nobel the younger and Andrietta Nobel (*née* Ahlsell) (Figure 3) [3–13]. The Nobels were descendants of Scanian farmers from the southern tip of Sweden (Skåne), and the name, which was originally Nobelius, was assumed by the first family member who attended a university and who had been born in the parish of Nöbbelöv [9]. Alfred's father was a self-educated builder, industrialist, and inventor, and his great-great-great-grandfather, the physician, anatomist, and botanist Olof Rudbeck (1630–1720) [14], was one of the most prominent Swedish scientists of the 17th century, the intellectual leader of Uppsala University, and founder of musical life in Uppsala.

In the year of Alfred's birth his father became bankrupt and in 1837 went to Finland to make a fresh start. He later moved to St. Petersburg, Russia, where he founded a business that manufactured machinery, iron goods, and military equipment. In 1842 he moved his wife and three sons, who had remained behind in Stockholm, to St. Petersburg, where Alfred and his brothers were tutored privately by Russian and Swedish tutors (1843–1850). Alfred's oldest brother, Robert, developed the important oil industry in Baku on the Caspian Sea, and his older brother, Ludvig, founded a world-renowned arms factory in St. Petersburg (Figure 4) [15].

Alfred spent two years studying chemistry in Germany, Italy, and North America, but mostly in Paris, where he spent a year with Théophile-Jules Pelouze (1807–1867) [16] of the Collège de France, who had just opened his private chemistry laboratory to students. In addition to being a scientifically trained chemist, Alfred became an excellent linguist, having mastered English, French, German, and Russian in addition to his native Swedish. During the Crimean War (1853–1856), he and his two older brothers worked in the St. Petersburg factory of his father, who again went bankrupt after the war when the Russian government canceled its orders of war *matériel*. In 1859 his father returned to Sweden, leaving his three older sons in Russia to salvage whatever they could from the business. During these years, Alfred received the first of his numerous patents—for a gasometer, water meter, and barometer—which whetted his appetite for a career as an inventor (Figure 5) [17].

Nobel's Percussion Detonator

For more than 500 years black powder had been the only known explosive. When Immanuel Nobel wanted to find a better one for use in his mines, Nikolai Nikolaevich Zinin (1812–1880) [18], the first chemist to synthesize aniline and who had taught chemistry to Alfred and his brothers, suggested nitroglycerin, which had been discovered in 1847 by Italian chemist Ascanio Sobrero (1812–1888) (Figure 6) [19]. Alfred had met the young Italian chemist when Sobrero was Pelouze's assistant in Paris.

Sobrero's face had been badly scarred in an accident during the 1840s, and he considered nitroglycerin to be too dangerous to be of any practical use. He is quoted to have said [19]:

> When I think of all the victims killed during nitroglycerin explosions, and the terrible havoc that has been wreaked, which in all probability will continue to occur in the future, I am almost ashamed to admit to be its discoverer.

Alfred returned to Sweden in 1863, and he and his father resumed their studies of nitroglycerin (actually glyceryl trinitrate, $C_3H_5(ONO_2)_3$), for which no reliable detonating method was known, working independently on different aspects of the problem. Sobrero was mortified by their commercial exploitation of his unstable discovery [19]. In 1863 Alfred made what many consider his most important invention—a percussion detonator called the "Nobel lighter."

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Figure 1. Nobel Prize Centennial 1901–2001 logo. Courtesy of the Nobel Foundation.

Figure 2. Alfred Nobel (1833–1896). Courtesy of the Nobel Foundation.

This device, when finally perfected, consisted of a small charge of mercury(II) fulminate ($Hg(CNO)_2$) in a metal cap [20]. When the detonator was exploded by a fuse, it produced a strong shock that triggered the explosion of the nitroglycerin. This invention, which introduced the “initial ignition principle” of using a shock rather than heat into blasting technique, provided much better control than when nitroglycerin was used alone. It made possible the application of this and all high explosives discovered later and is considered the greatest advance in the science of explosives since the explosion of gunpowder.

Nobel had been sickly as a child, and as an adult he suffered painful attacks of angina pectoris, recurrent headaches, depression, and digestive disturbances. Shortly before his death, he wrote to a colleague [21]:

> Isn’t it the irony of fate that I have been prescribed nitroglycerin, to be taken internally! They call it Trinitrin, so as not to scare the chemist and the public.

However, from his work with the substance Nobel knew that it caused severe headaches, so he did not take it for his heart problem.

Nitroglycerin, an Unpredictable Explosive

In 1864 Nobel and his father set up a small laboratory for producing nitroglycerin at Heleneborg, a suburb of Stockholm. The liquid is a very dangerous and unpredictable explosive because it can be detonated unexpectedly by shock, heat, friction, or other means. Therefore Alfred tried to discover a method of controlling it. On September 3, 1864 the laboratory

Figure 3. Alfred Nobel’s parents, Andrietta and Immanuel Nobel. Courtesy of the Nobel Foundation.

Figure 4. Nobel brothers Alfred (left) and Ludvig (right) in St. Petersburg, probably in the late 1840s. They worked in the family factory Fonderies et Ateliers Mécaniques Nobel & Fils (Nobel & Sons Iron Factory & Mechanical Workshop). Courtesy of the Nobel Foundation.

exploded, killing five persons including his younger brother Emil, who had been born after the family moved to St. Petersburg. Alfred’s father was crushed by his death and suffered a stroke several weeks later. Although he recovered somewhat, he never regained his physical or mental faculties, and he died in 1872.

It was a time before environmental impact reports, but the city government refused to permit the laboratory to be rebuilt in a populated area. Nobel therefore continued his experiments in Lake Mälaren on a barge, the position of which he changed as required by protests from persons in the vicinity. Despite the hazards of this unstable explosive, in 1865 the Nobels built the world’s first full-scale nitroglycerin manufacturing plant in Vinterviken, an isolated area near Stockholm. Alfred was its managing director, plant engineer, salesman, advertising agent, correspondent, and treasurer. His career as an industrialist began at this point. The market continued to grow, and the Nobels built another plant at Krümmel near Hamburg, Germany, from which nitroglycerin was shipped to various countries.

The Invention of Dynamite

The accidents with nitroglycerin continued, and Alfred devoted himself to taming the unpredictable liquid. He mixed it with various materials, eventually selecting diatomaceous earth (*Kieselguhr*). When he was only 33 years old, he found that a mixture of three parts of nitroglycerin to one part of *Kieselguhr* possessed 75 percent of the explosive power of pure nitroglycerin but was free of its unpredictable hazards. It

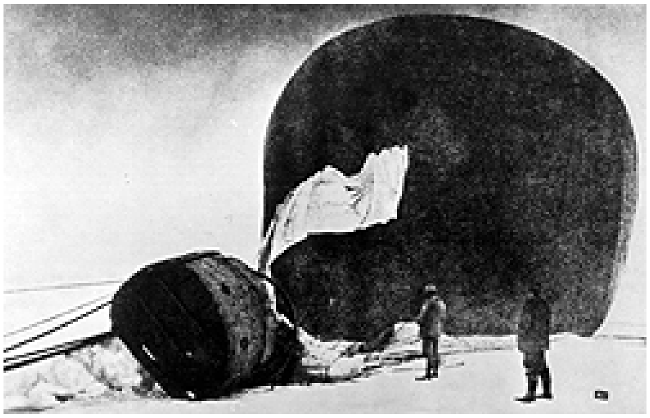


Figure 5. Alfred Nobel supported Swedish engineer S. A. Andrée's balloon to the North Pole, but his ideas for improving the balloon were never adopted. Courtesy of the Nobel Foundation.

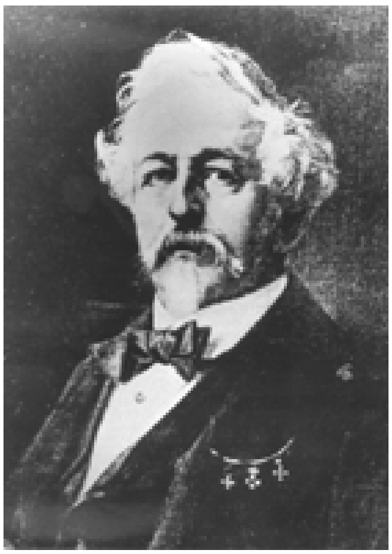


Figure 6. Ascanio Sobrero (1812–1888). Courtesy of the Nobel Foundation.

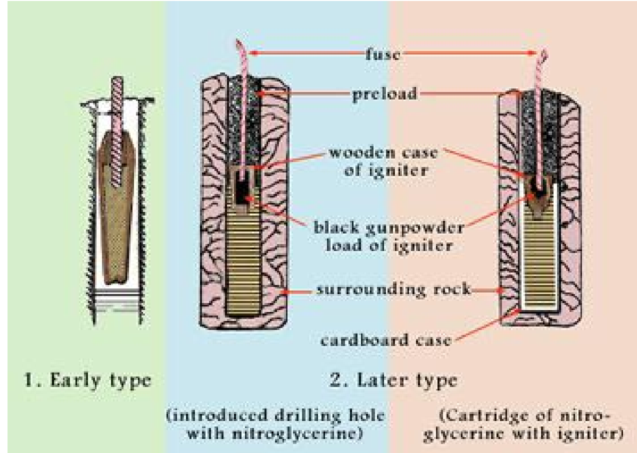


Figure 7. Nitroglycerin and dynamite. Courtesy of the Nobel Foundation.

Figure 8. Alfred Nobel in his Bofors laboratory in Sweden. A modest man who avoided all publicity, he never had his portrait painted. This portrait was painted 22 years after his death. Courtesy of the Nobel Foundation.

could not be exploded without a detonating cap and thus could be transported and handled with relative safety. It could be put into rolled paper tubes that could be inserted directly into bore holes at any angle. Nobel called his mixture "dynamite" (from the Greek δυναμις, meaning "power") (Figure 7) [22]. He patented it in Sweden and Great Britain in 1867 and in the United States in 1868. Some persons maintain that Nobel's invention was an accidental discovery, but Erik Bergengren, who had the Nobel Foundation's support and complete access to its files, stated that Nobel vehemently denied this and that the story is not true [8, pp 44–45].

Dynamite was rapidly adopted and was of tremendous importance in replacing back-breaking human labor. It was an essential aid in excavation for mines, roads, railroads, canals, and tunnels, and many projects that we take for granted today would be impossible without it. Gigantic projects in which dynamite was used during Nobel's lifetime include the St. Gotthard railroad line in Switzerland (1882), the Corinth Canal, crossing the Isthmus of Corinth to join the Gulf of Corinth with the Saronic Gulf (295 feet deep and nearly four miles long, 1893), and the clearing of the Danube at the Iron Gate (1896).

Nobel eventually built 93 factories in 21 countries to manufacture dynamite. He was heavily involved in the commercial aspects of his numerous enterprises, but he disliked them and always longed to return to his laboratory. Being without a secretary, private office, or permanent lawyer, he personally answered all his mail in the correspondents' own language and wrote, copied, and registered all letters himself.

Blasting Gelatin and Other Inventions

Because an even more powerful blasting agent than dynamite was needed for use with very hard rock, Nobel tried to improve it by replacing the inert *Kieselguhr* with something that could participate in the explosion. He succeeded in this attempt with a discovery that was truly accidental [8, pp 73–74]. In 1875 he cut his finger in his laboratory and coated the wound with collodion, a solution of nitrocellulose (cellulose nitrate, guncotton, or pyroxylin) in a mixture of alcohol and ether, a common treatment for cuts. The solution dries rapidly to yield a thin, elastic film providing both pressure and protection for the wound. That night, unable to sleep because of the pain, he conceived the idea of mixing collodion with nitroglycerin, thus combining two explosives in one mixture. The new product, which he called "blasting gelatin," was more powerful than dynamite and soon became a commercial success.

In 1887 Nobel developed "ballistite," a mixture of nitrocellulose, nitroglycerin, benzene, and (initially) camphor, one of the first smokeless powders for military use. It was first used for this purpose in Italy, and from this time on Nobel came to be associated with war (Dynamite and blasting gelatin are not useful military explosives).

Throughout his life Nobel continued to experiment and invent—his primary interest. In addition to explosives, he worked on artificial silk, rubber and leather substitutes, nitrocellulose lacquers, precious stones from fused alumina (Al_2O_3), and improvements in electric batteries and telephones, to mention only a few of his multifarious projects (Figure 8) [23]. Although the exact number of his patents is unknown, at least 335 in different countries were listed in the settlement of his estate.

Nobel was involved in many lawsuits over patent rights, and he did not possess a monopoly on his discoveries. He made little profit in the United States, where he encountered numerous unethical practices; however, his inventions made him a fortune, which was enhanced by his investments in his elder brothers' project in the Baku oil fields. Indeed, he was one of the leading industrialists of the 19th century.

A Benevolent Recluse

Nobel was a truly cosmopolitan figure, traveling widely on business and living in Hamburg (1865–1873), Paris (1873–1891), and San Remo, on the Italian Riviera, just across from the French border (from 1891 until his death). He was jokingly referred to as "Europe's wealthiest vagabond" [7; 8, pp 35, 160–161]. He himself said, "My home is where my work is, and I work everywhere" [17]. He was a mixture of contradictions. Although he corresponded with and was involved with many of the most famous personalities of the 19th century, he described himself as shy and lonely [24]:

> I am a misanthrope and yet utterly benevolent, have more than one screw loose, yet am a super-idealist who digests philosophy more efficiently than food.

Nobel was a complex person and could be described as brilliant, cultured, modest, rich, principled, well-informed, unassuming, and unhappy. A sensitive person who thought deeply about philosophical issues, he was disappointed in love, never married, had few close friends, and suffered from chronic loneliness. He died suddenly of a cerebral hemorrhage on December 10, 1896, surrounded by only a few friends. His death was as lonely as his life. Formal funeral rites were held on December 29, 1896 in the old Stockholm cathedral (*Storkyrkan*), and, after a solemn procession to the New Cemetery (*Nya Kyrkogården*), he was cremated in accordance with the wish expressed in his will [9, p 38].

Nobel's Will

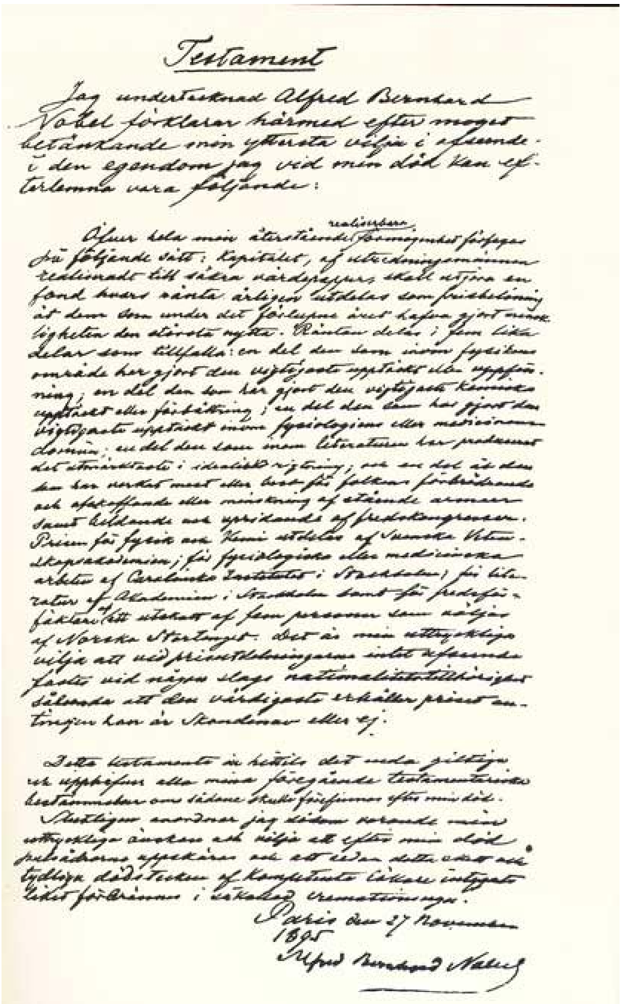
Nobel thought about donating his fortune over a period of years and had written and rewritten his will on several occasions [13]. He originally intended that after his death most of his wealth should be used for annual prizes "for the most outstanding discoveries or theories in the wide field of learning and progress as a whole" [25, p 281]. He abandoned this idea in his final will, however, and directed that the prizes should be awarded in specific fields, one of the most important of which was his own profession—chemistry. His estate of more than 33 million Swedish kronor (crowns)—about $9,200,000—was a very large amount for that time. Because he thought it unwise to leave large sums to heirs, he decided to use the interest from his fortune to fund the annual awards that carry his name. At that time it was unusual to donate large amounts of money for charitable or scientific purposes [13]. His final last will and testament, written and signed at the Swedish–Norwegian Club in Paris and dated November 27, 1895, about a year before his death, was a four-page handwritten document, which, after some personal bequests [26], outlined his wishes for the prizes [9, pp x-xi] (Figure 9):

> The whole of my remaining realizable estate shall be dealt with in the following way: The capital shall be invested by my executors in safe securities and shall constitute a fund, the interest on which shall be annually distributed in the form of prizes to those who, during the preceding year, shall have conferred the greatest benefit on mankind. The said interest shall be divided into five equal parts, which shall be apportioned as follows: one part to the person who shall have made the most important discovery or invention in the field of physics; one part to the person who shall have made the most important chemical discovery or improvement; one part to the person who shall have made the most important discovery within the domain of physiology or medicine; one part to the person who shall have produced in the field of literature the most outstanding work of an idealistic tendency; and one part to the person who shall have done the most or the best work for fraternity among nations, for the abolition or reduction of standing armies and for the holding and promotion of peace conferences. The prizes for physics and chemistry shall be awarded by the Swedish Academy of Sciences (*Svenska Vetenskapsakademien*); that for physiological or medical works by the Caroline Institute in Stockholm (*Carolinska Institutet i Stockholm*); that for literature by the Academy in Stockholm (*Academien i Stockholm*); and that for champions of peace by a committee of five persons to be elected by the Norwegian Parliament (*Norska Stortinget*). It is my express wish that in awarding the prizes no consideration whatever shall be given to the nationality of the candidates, so that the most worthy shall receive the prize, whether he be a Scandinavian or not.

The Five Fields of Culture

The specific domains of human endeavor that Nobel chose to promote and recognize by his prizes are consistent with his lifelong interests, especially his interest in science [27]. The thread of chemistry, which brought him his industrial success, runs through the three prizes in science. His training was in chemistry, and his work on explosives was primarily chemical.

Nobel's ideas about physics emphasized the interactions of atoms, a primary concept of both chemistry and physics. In a letter he wrote [24]:


Testament

Jag undertecknad Alfred Bernhard Nobel förklarar härmed efter moget betänkande min yttersta vilja i afseende å den egendom jag vid min död kan efterlemna vara följande:

Paris den 27 November 1895

Alfred Bernhard Nobel

Figure 9. Alfred Nobel's handwritten will establishing the prizes, November 17, 1895 [7, pp x-xi]. Courtesy of the Nobel Foundation.

> I have to admit…that I harbor the most lively interest for…the Atom. Its shape, movements, fate, etc., both individually and as a participant in the life of the Cosmos, fascinate me.

In 1890, in his laboratory journal, he made a list of "Philosophical Reflections to Be Written," including two essays that bridged the then-recognized border between physics and chemistry—"The Interacting Atoms" and "The Ether and Ponderable Matter;" however, he never got around to writing either of these articles.

The prize in physiology or medicine evolved both from his general scientific curiosity and his lifelong illnesses. His research on medical subjects dealt with chemical composition and reactions, for example, he sought to invent tubing for transfusions that would minimize coagulation of blood.

Beginning with his childhood, Nobel wrote unpublished stories, a play, a novel, and poems (many written in English before he was twenty), in which he sought to transform norms, values, and social conditions. He possessed many of the *desiderata* of the poet—deep feeling and considerable powers of imagination. In later life, despite his heavy scientific and commercial obligations, he followed current literary developments. His interest focused on the ideas conveyed, and he regarded literature primarily "as a source of health for humanity in its progress toward the future about which he dreamt. To this concept, his will also bears witness" [9, p 13]. As late as 1895, the year before his death, he wrote and had privately printed a play, *Nemesis*, originally titled *The Death of Cenci*, on the same theme as Percy Bysshe Shelley's (1792–1822) renaissance tragedy *The Cenci* (1819) [27, pp 78–79].

Throughout his life Nobel loathed war, which he regarded as "the horror of horrors and the greatest of all crimes" [13]. He considered his explosives useful tools for peaceful enterprises (We have already seen that dynamite and blasting gelatin were not military explosives.); however, the general public viewed his explosives as being used mainly for aggressive purposes and his great wealth as derived primarily from armaments. In 1888 Nobel was surprised and shocked to read his obituary in a Paris newspaper calling him "a merchant of death" (He had been confused with his recently deceased older brother Ludvig) [11]. In his *Talks to the Swedish People* [28], Sweden's greatest playwright and author, August Strindberg (1849–1912) [29], perhaps in his disappointment at not having received the Nobel Prize in Literature and laboring under the above mentioned misconception about the military use of dynamite, referred to "Nobel money—some say dynamite money" as "morally tainted" [30, p 35].

Some envious persons, possibly because of a need to sully the reputations of historical figures, have speculated that his philanthropy might have its roots in an expiation of guilt rather than concern with humanity. Actually, "he was a complete pacifist, but in regard to the proposed methods of making war impossible he was rather skeptical" [9, p 11]. Instead, he believed that his explosives would make war so terrible that it would be abandoned as a method for settling disputes between nations. When Austrian Baroness Bertha von Suttner (1843–1914), to whom he was romantically attracted [31] and who was later (1905) to receive the Nobel Peace prize, asked him to participate in a Peace Congress in Berne, Switzerland in 1892, he told her [9, p 12; 11]:

> My factories will put an end to war sooner than your Congresses. When the day dawns that two army corps can destroy each other in one second, all civilized nations will surely recoil from war in horror and disband their armies.

Unfortunately, history has shown him to be mistaken in this sanguine supposition.

The Will's Complications

Because of his great distaste for lawyers, Nobel had prepared his will without any legal advice or lawyer's assistance, and consequently it had numerous defects [7]. He left his estate to a foundation but failed to establish one, and he never consulted any of the organizations charged with selecting the prize recipients about their willingness to accept this responsibility. Also, relatives and other individuals emerged with unexpected claims on his estate [30, pp 37–68].

Bitter attacks in the press and elsewhere, with the support of Nobel's closest relatives, were directed against the fundamental idea of his will, and attempts were made to declare the entire will invalid. Ragnar Sohlman, one of the will's executors, discusses the will's settlement in great detail [30, pp 37–68] and lists the principal charges made against it [30, p 42; 32]:

Figure 10. Nobel Prize laureates 1901 (physics, chemistry, physiology or medicine, and chemistry). Courtesy of the Nobel Foundation.

Figure 11. Jacobus Henricus van't Hoff (1852–1911). Courtesy of the Nobel Foundation.

> the outright lack of patriotism shown by a Swede who, while neglecting Swedish national interests, had wanted to support, instead, certain international activities; the incapacity of the institutions designated as prize awarders to perform satisfactorily the duties entrusted to them, which would, furthermore, interfere with their normal activities and expose their members to attempts at bribery and corruption; and, finally, that the Peace Prize was to be awarded by a committee appointed by the parliament of Norway, which was held to involve the greatest dangers to Swedish interests, particularly in view of Sweden's strained relations with Norway over the union that was then in force.

After prolonged negotiations with the heirs and the prize-awarding institutions, on September 9, 1898 the Swedish government gave its formal approval of the will. The ambiguities in the will were clarified, the award selection process was decided upon, and the use of income from the funds was approved. Finally, the definitive text of the proposed "Statutes of the Nobel Foundation," as agreed upon by the committee members, was approved on April 27 and 28, 1900 and submitted by the executors to the Swedish government, which approved them and officially promulgated them as a governmental decree on June 29, 1900.

The First Prizes

The first awards were presented in Stockholm by King Gustav V (1858–1950), then still Crown Prince (the great-grandfather of Sweden's present king, Carl XVI Gustav (b. 1946)), on December 10, 1901, the fifth anniversary of Nobel's death (Figure 10) [35]. Since then, the awards have been presented personally to the laureates in Stockholm by the King of Sweden on December 10 except for the Peace Prize, which is presented in Oslo on the same date. Each laureate presents a lecture in connection with the award ceremonies.

Jacobus Henricus van't Hoff (1852–1911) of The Netherlands received the Nobel Prize in Chemistry (*Nobelpriset i Kemi*) "for the discovery of the laws of chemical dynamics and osmotic pressure in solutions" (Figure 11) [25, 36]. Wilhelm Conrad Röntgen (1845–1923) of Germany received the first Nobel Prize in Physics (*Nobelpriset i Fisik*) "for the discovery of the remarkable rays [X-rays] subsequently named after him" [37].

Sully Prudhomme (synonym of René-François-Armand Prudhomme, 1839–1907), the French poet, received the Nobel Prize in Literature (*Nobelpriset i Litteratur*) "in special recognition of his poetic compositions, which give evidence of lofty idealism, artistic perfection and a rare combination of the qualities of both heart and intellect" [27, p 93]. German physician and bacteriologist Emil von Behring (1854–1917) received the Nobel Prize in Physiology or Medicine (*Nobelpriset i Fysiologi eller Medicin*) for his work on serum therapy, especially its application against diphtheria [38, pp 159–160]. Jean-Henri Dunant (1828–1910), the Swiss founder of the Red Cross and founder of the World's Young Men's Christian Association renowned for his work for prisoners of war, and the French economist and advocate of international arbitration Frédéric Passy (1822–1912) shared the Nobel Peace Prize (*Nobels Fredspris*) [39, pp 490-494].

The first Prize for Economic Sciences in Memory of Alfred Nobel (*Priset i Ekonomisk Vetenskap till Alfred Nobels Minne*) was awarded in 1969 to Ragnar Frisch (1895–1973) of Norway, a pioneer in econometrics—the application of mathematical models with statistical techniques to economic data, a term that he invented, and Jan Tinbergen (1903–1994) of The Netherlands, an econometrics pioneer, who developed business-cycle theory and the application of methods of economic stabilization.

In 1954 accounts of the Nobel laureates and their works for the first fifty years of the prizes in chemistry [40], physics [41], and physiology or medicine [42] were published, and in 1948 a collection of the most representative writings of Nobel laureates in literature appeared [43]. For the chemistry prize, a collection of biographies of the first 114 men and three women to receive the prize appeared in 1993 [44].

Since 1901 the Nobel Foundation has published annually *Les Prix Nobel*, containing reports from the award ceremonies in Stockholm and Oslo as well as biographies and Nobel lectures of the laureates. To make the biographies and lectures available to persons with special interests in the five different prize fields, the Nobel Foundation granted the Elsevier Publishing Company the right to publish, in English, the lectures for 1901–1970 in separate volumes. Thereafter, the foundation granted the World Scientific Publishing Company the right to continue these series and also to publish the Nobel Prize lectures in Economics from the year 1969. In addition to the print volumes for chemistry [45], the chemistry lectures for 1901–1995 are available on a single CD-ROM [46]. In conjunction with the Centennial Exhibition of the Nobel Prize [47], a special volume was published [48]. Through the years books on the laureates and the prizes have been published regularly, and several books on the occasion of the centennial have appeared [49, 50].

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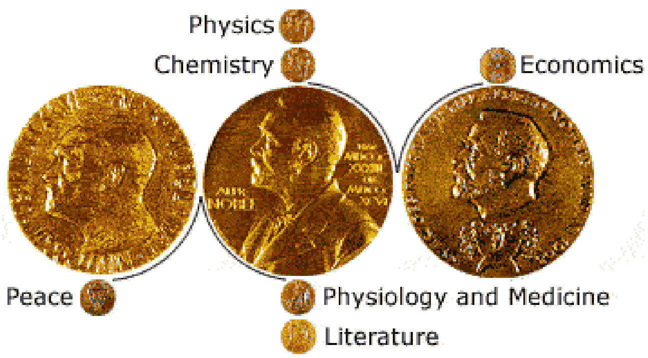

Figure 12. The Nobel medal, obverse side, designed by Swedish sculptor and engraver Erik Lindberg. Courtesy of the Nobel Foundation.

Figure 13. The Royal Swedish Academy of Sciences. Courtesy of the Nobel Foundation.

Figure 14. The Nobel Prize medal for physics and chemistry, reverse side, designed by Swedish sculptor and engraver Erik Lindberg. Courtesy of the Nobel Foundation.

The Nobel Prize

According to the Statutes of the Nobel Foundation, "the prize-awarding bodies shall present to each prize-winner an assignment for the amount of the prize, a diploma, and a gold medal bearing the image of the testator and an appropriate inscription" [33, 51, 52]. Although the Nobel Foundation is the legal owner and functional administrator of the funds and serves as the joint administrator of the prize awarders, it is not concerned with the prize deliberations or decisions, which rests with the four institutions specified in Nobel's will [53].

The medals for chemistry, physics, physiology or medicine, and literature were modeled by Swedish sculptor and engraver Erik Lindberg [54]. The obverse (front) sides of these are all identical, with Alfred Nobel's portrait and the dates of his birth and death in Latin—"NAT-MDCCCXXXIII OB-MDCCCXCVI" (Figure 12) [52]. The main inscription on the reverse sides reads "INVENTAS VITAM JUVAT EXCOLUISSE PER ARTES," loosely translated as "And they who bettered life on earth by new found mastery" (literally, "inventions enhance life which is beautified through art") [54, 55], while the images vary according to the symbols of the particular prize-awarding institutions.

For the chemistry and physics prizes, awarded by the Royal Swedish Academy of Sciences (Figure 13), Nature is represented in the form of a goddess resembling Isis, emerging from the clouds and holding a cornucopia in her arms. The veil covering her face is held up by the Genius of Science. The laureate's name is engraved on the plate below the figures and the Latin abbreviation "REG. ACAD. SCIENT. SUEC." (Royal Swedish Academy of Sciences) (Figure 14) [54]. For the diplomas the Swedish Academy has always used individual designs summarizing the atmosphere and character of each laureate's work [57].

The Selection Process

The selection process begins in the early autumn of the year before the awards, when the prize-awarding institutions mail invitations to nominate candidates to those persons qualified to do so according to the Nobel statutes [33, 34]. Recipients are selected on the basis of professional competence and the international range of their contributions. The prizes are open to anyone, regardless of nationality, race, creed, or ideology, but self-nominations are not accepted. Nominations in writing must reach the particular committee before February 1 of the year that the prize is awarded. Those received after the deadline are considered for the following year's prize [33, 34].

On February 1 the six Nobel committees begin to consider the nominations that they have received. They can call in authorities of any nationalities if they deem it necessary. The committees submit to their respective prize-awarding bodies their recommendations, which are usually but not always accepted. The deliberation and voting are secret at all stages. Although the final decisions must be made by November 15 [53], recently the prize announcements have been made in early October. Except for the Peace Prize, which may be given to an institution, prizes are awarded to individuals.

Prizes can be awarded more than once to the same recipient. Thus, within the same field, chemistry, Frederick Sanger of England (b. 1918) received the 1958 prize "for his work on the structure of proteins, especially insulin" [40, pp 282–289; 44, pp 406–411] and shared one-half of the 1980 prize with the American Walter Gilbert (b. 1932) "for their contributions concerning the determination of base sequences in nucleic acids" [44, pp 626–638] (Paul Berg, an American (b. 1926), won the other half "for his fundamental studies of the biochemistry of nucleic acids, with particular regard to recombinant-DNA") [44, pp 618–625].

Similarly, but in different fields, Polish-born Frenchwoman Marie Sklodowska Curie (1867–1934), the first scientist to receive two Nobel prizes, shared one-half of the 1903 physics prize with her husband Pierre Curie (1859–1906) "for their

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joint researches on the radiation phenomena discovered by Professor Henri Becquerel." (Frenchman Becquerel (1852–1908) won the other half "for his discovery of spontaneous radioactivity"). She also won the 1911 chemistry prize "for her services to the advancement of chemistry by the discovery of the elements radium and polonium, by the isolation of radium and the study of the nature and compounds of this remarkable element" [40, pp 45–48; 44, pp 75–82]. If Pierre Curie had not been run over by a dray in 1906, he would have undoubtedly shared her second prize.

The American Linus Carl Pauling (1901–1994) won the 1954 chemistry prize "for his research into the nature of the chemical bond and its application to the elucidation of the structure of complex substances" [40, pp 247–253; 44, pp 368–379] and the 1962 peace prize, thus becoming the only person to be awarded two unshared Nobel prizes. In his presentation speech, Nobel Peace Prize Committee Chairman Gunnar Jahn described Pauling as one, "who, since 1946 has campaigned ceaselessly, not only against nuclear weapons tests, not only against the spread of these armaments, not only against their very use, but against all weapons as a means of solving international conflicts" [58].

An individual may not be nominated posthumously, but a prize already proposed may be so awarded, e.g., the 1931 Literature Prize to the Swede Erik Axel Karlfeldt (1864–1931), who died while his candidature was under formal consideration [27, pp 112–113], and the 1961 Peace Prize to another Swede, Dag Hammarskjöld (1905–1961), who was killed on September 17, 1961 in an airplane crash en route to Katanga [39, pp 577–580]. Until 1974 an individual could be awarded a prize posthumously if the nomination was made before February 1 of the same year. Since then the prize may be awarded to a deceased person who has been named as winner for the year, usually in October, but who dies before the prize awarding ceremony on December 10 [51]. Diplomatic or political support for a candidate has no effect on an award because the prize awarders are independent of the state.

Initially, more than three winners could share a prize, although this practice never took place [51]. In 1968 paragraph 4 of the Nobel statutes was amended to restrict the number of prize winners [33, 34, 59]:

> A prize may be equally divided between two works each of which may be considered to merit the prize. If a work which is to be rewarded has been produced by two or three persons, the prize shall be awarded to them jointly. In no case may a prize be divided between more than three persons.

The first time that the prize in chemistry was divided was in 1912 when it was shared equally between two Frenchmen—Victor Grignard (1871–1935) "for the discovery of the so-called Grignard reagent, which has greatly helped in the development of organic chemistry during these last years" [40, pp 49–51; 44, pp 83–87; 45a, pp 234–249] and Paul Sabatier (1854–1941) "for his method of hydrogenating organic compounds in the presence of finely divided metals" [40, pp 51–55; 44, pp 88–92; 45a, pp 221–233]. The first time that the chemistry prize was divided between three persons was in 1946 when it was shared between three Americans. Half was awarded to James B. Sumner (1887–1955) "for his discovery that enzymes can be crystallized" [40, pp 189–191; 44, pp 288–293; 45c, pp 114–123], and half was awarded equally to John Howard Northrup (1891–1987) [40, pp 294–299; 45c, pp 124–136] and Wendell Meredith Stanley (1904–1971) "for their preparation of enzymes and virus proteins in a pure form" [40, pp 192–197; 44, pp 300–305; 45c, pp 137–159]. The first American to receive the chemistry prize was Theodore William Richards (1868–1928) "for his exact determinations of the atomic weights of a great number of chemical elements" [40, pp 61–64; 44, pp 100–107; 45a, pp 275–294].

Occasionally, a prize is withheld until the following year [53, 60]. For the chemistry prize this has occurred eight times. The 1918 prize was awarded in 1919 to Fritz Haber (1868–1934) of Germany "for the synthesis of ammonia from its elements, nitrogen and hydrogen" [40, pp 71–75; 44, pp 114–124]. The 1920 prize was awarded in 1921 to another German, Walther Nernst (1864–1941), "for his thermochemical work" [40, pp 76–80; 44, pp 125–133]. The 1921 prize was awarded in 1922 to an Englishman, Frederick Soddy (1877–1956), "for his contributions to the chemistry of radioactive substances and his investigations into the origin and nature of isotopes" [40, pp 81–85; 44, pp 134–139]. The 1925 prize was awarded in 1926 to Richard Zsigmondy (1865–1929) of Austria "for his elucidation of the heterogeneous nature of colloid solutions and for the methods he has devised in this connection, which have since become of fundamental importance in modern colloid chemistry" [40, pp 95–98; 44, pp 151–157]. The 1927 prize was awarded in 1928 to Heinrich Wieland (1877–1957) of Germany "for his research on bile acids and analogous substances" [40, pp 103–106; 44, pp 164–168]. The 1938 prize was awarded in 1939 to another German, Richard Kuhn (1900–1967), "for his work on carotinoids and vitamins" [40, pp 165–167; 44, pp 248–252]. The 1943 prize was awarded in 1944 to a Hungarian, George de Hevesy (1885–1966), "for his work on the use of isotopes as tracer elements in researches on chemical processes" [40, pp 176–180; 44, pp 266–271]. The 1944 prize was awarded in 1945 to Otto Hahn (1879–1968) of Germany "for his discovery of the fission of heavy nuclei" [40, pp 181–184; 44, pp 272–281].

Two prizes in the same field can be awarded in the same year—the prize withheld from the previous year and the current year's prize [53]. For the chemistry prize, this has occurred five times. In 1922 the prize was awarded to Francis William Aston (1877–1945) of England "for his discovery, by means of his mass spectrograph, of the isotopes of a large number of non-radioactive elements, as well as for his discovery of the whole-number rule" [40, pp 86–90; 44, pp 140–145] at the same time that another Englishman, Frederick Soddy, received the 1921 prize. In 1926 the prize was awarded to Theodore Svedberg (1884–1971) of Sweden "for his work on disperse systems" [40, pp 99–102; 44, pp 158–163] at the same time that Austrian Richard Zsigmondy received the 1925 prize. In 1928 the prize was awarded to Adolf Windaus (1876–1959) of Germany "for his studies on the constitution of the sterols and their connection with the vitamins" [40, pp 107–110; 44, pp 169–174] at the same time that another German, Heinrich Wieland, received the 1927 award. In 1939 one-half the prize was awarded to Adolf Butenandt (1903–1995) of Germany "for his work on sex hormones" [40, pp 168–170; 44, pp 253–258], and one-half was awarded to the Croatian-born Leopold Ružička (1887–1967) of Switzerland "for his work on polymethylenes and higher terpenes" [40, pp 171–174; 44, pp 259–265] at the same time that Richard Kuhn of Germany received the 1938 award. In 1945 the prize was awarded to Artturi Ilmari Virtanen (1895–1973) of Finland "for his researches and inventions in agricultural and nutritive chemistry, especially for his method of fodder preservation" [40, pp 185–188; 44, pp 282–287] at the same time that Otto Hahn of Germany received the 1944 award.

If a prize is declined or not accepted before a set date, the prize money reverts to the funds. Prizes have been declined, and in some cases governments have forbidden their citizens to accept them; however, those who are awarded a prize are entered into the list of Nobel laureates with the designation "declined the award." Although the reasons for declining may vary, the real reason has usually been external pressure, for example, Adolf Hitler's decree of 1937 forbade Germans to accept Nobel Prizes because he considered the award of the 1935 Peace Prize to the German pacifist Carl von Ossietzky (1889–1938) to be an affront [53]. As a result the Germans Richard Kuhn and Adolf Butenandt declined the 1938 and 1939 Chemistry Prizes, respectively. (They were awarded the medals and diplomas after World War II—in July, 1949 [25, p 369].) In some cases the decliner has later explained his situation and on application has received the gold medal and diploma but not the money, which had reverted to the funds.

Prizes are either withheld or not awarded when no worthy candidate according to Nobel's will can be found or when the world situation prevents the gathering of information required to reach a decision as was the case during World Wars I and II. The Peace Prize has been most frequently reserved [53]. No Chemistry Prizes were awarded for the years 1916, 1917, 1919, 1924, 1933, 1940, 1941, and 1943.

Controversial Awards

Although awards may not be appealed [53], objections to the awards have been expressed from many quarters on some occasions. As we might expect, the scientific prizes (chemistry, physics, and physiology or medicine) have been the least controversial, whereas the peace and literature awards have been the most frequently criticized [53]. A recent exception to this generalization is provided by an open letter to the committee for the Physiology or Medicine Prize signed by more than 250 neuroscientists [61]. The letter writers complained that Oleh Hornykiewicz, Professor Emeritus at the Brain Research Institute of the Vienna University Medical School, who discovered the underlying neurotransmitter deficit in Parkinson's disease and devised the treatment still in use today, was not included in the 2000 award or even mentioned in the prize announcement.

Unlike the committees for the "Swedish" prizes, the Nobel Committee that awards the Peace Prize rarely gives any official reason for its decisions, a fact that has obviously increased the criticism of its choices. It has frequently been argued that, in opposition to Alfred Nobel's wishes, the committee has often neglected peace workers in favor of political opportunists or older persons [39]. Among the awards that have been widely criticized have been those to American president Theodore Roosevelt (1858–1919, awarded 1906), Carl von Ossietzky (1889–1938) of Germany (1935), Linus Pauling (1901–1994) of the U.S.A. (1962), Le Duc Tho of North Vietnam (who declined) and the German-born American, Henry A. Kissinger (b. 1923, awarded 1973), Rigoberta Menchú of Guatemala (b. 1959, awarded 1992), and the Palestinian, Yasir Arafat (b. 1929, awarded 1994).

Although the statutes have generally remained unchanged, they have been modified somewhat in their application, for example, the will's ambiguous wording "idealistic tendency" [9, pp x-xi] for the work for which the Literature Prize was to be awarded was initially interpreted strictly but has since been interpreted more flexibly [53]. Among writers who were of Nobel caliber, but for various reasons did not receive the award, may be listed: Leo Tolstoy of Russia, Henrik Ibsen of Norway, August Strindberg of Sweden [62], Thomas Hardy of England, Paul Valéry of France, Rainer Maria Rilke of Germany, and Émile Zola of France (nominated by French chemist and statesman Marcellin Berthelot).

Because of her private life, the widow Marie Curie was the target of vitriolic attacks in Parisian newspapers, which reached a crescendo at the time of her Nobel Prize in chemistry (1911). Rumors circulated of a love affair between her and French physicist Paul Langevin (1872–1946), who was married and the father of four children. Several articles included letters from Madame Curie to Langevin, which furnished the pretext for a xenophobic (She was Polish not French), antifeminist, and antiscience campaign. She replied immediately, and Langevin challenged a journalist to a duel and wrote a letter to Nobel Prize Committee chairman Svante Arrhenius. Madame Curie suffered a nervous breakdown as well as serious physical illnesses, and toward the end of December, 1911 she spent several weeks in a nursing home [44, p 80].

Because Fritz Haber had initiated and directed Germany's gas warfare during World War I, which also may have influenced his first wife Clara Immerwahr (1870–1915) to commit suicide, he became one of the world's most hated persons, and his 1918 Chemistry Prize (awarded in 1919) was greeted with widespread protests [63].

In some cases, a pronounced animus against a nominee has delayed the award of a prize. For example, the Swede Svante Arrhenius viewed science in an adversarial manner, and he was often involved in considerable polemics with other scientists. For example, in later life he pursued a conflict with 1908 Nobel Physiology or Medicine laureate, the German Paul Ehrlich (1854–1915), over toxin–antitoxin reactions, which set the agenda for several years of theoretical and experimental work by both of them. An unfortunate consequence of this antagonism was Arrhenius' use of his influential position to block for a decade and a half the Nobel Prize of the German, Walther Nernst, his former friend but later Ehrlich's ally [64]. Nernst was nominated annually from 1906 to 1921, but he did not receive the prize until 1920 (awarded in 1921) [65, pp 170-221).

Neglected Chemists

In contrast to the Peace Prizes, where the focus of protests has been primarily against the awarding of the prizes to particular individuals, in the case of the Chemistry Prizes, with the exception of a few cases, some of which have just been mentioned, the focus has been on the neglect of worthy individuals who were not awarded the prize.

According to Nobel's will, the prize should be awarded for work "during the preceding year" [9, p x]; however, the statutes have interpreted this provision to include the most recent results or for older work if its significance has been demonstrated only recently. Even with these additional clarifications, the decision on awarding the Chemistry Prize has been a difficult task [25].

In 1974 the Nobel Foundation relaxed the statutes' provision that all deliberations concerning the prizes be kept secret and allowed the four prize-awarding institutions to permit access to their archival materials to qualified scholars for purposes of historical research, provided these documents were at least 50 years old. For the Chemistry and Physics Prizes, data on the nominators and nominees are available in handy book format [65].

During the Nobel Chemistry Prize's early years a number of the 19th century's greatest chemists were still alive, and the number of chemists considered worthy of the prize was greater then than it has ever been since [25, pp 284, 288]. For example, the Italian Stanislao Cannizzaro (1826–1910), whose resurrection of his fellow countryman Amedeo Avogadro's (1776–1856) law of 1811 permitted the clear distinction between atom and molecule that allowed the accurate determination of atomic weights, merited the prize. Strangely enough, he was not nominated until he was 81, in 1907 (three nominations), the year that the German Eduard Buchner (1860–1917) won the prize (two nominations); however, because so many years had passed since the publication of Cannizzaro's *Sunto di un corso di philosofia chimica* (1859), the statutes' restriction that older work could be considered only if its significance had not been demonstrated until recently, took him out of the running [25, pp 285–286; 65, pp 172–175].

Although the American Josiah Willard Gibbs (1839–1903) and his pioneering work on thermodynamics were not recognized until the early years of the prize and, therefore, could have received the prize, he was never nominated [25, pp 286–287]. The Dane (Hans Peter Jürgen) Julius Thomsen (1826–1909) and the Frenchman (Pierre Eugène) Marcellin Berthelot (1827–1907) are universally regarded as the founders of thermochemistry and together were awarded the Royal Society's Davy Medal in 1883, yet neither of them received the prize. Thomsen was never nominated, but Berthelot was nominated for six different years (1901–1904, 1906, 1907), and in 1902 he received five nominations, the same number as the actual winner, the German Emil Fischer (1852–1919) [25, pp 287–288; 65, pp 158–165, 170–173].

The American astronomer Harlow Shapley (1885–1972) called the periodic table "probably the most compact and meaningful compilation of knowledge that man has yet devised" [66]. The Englishman William Ramsay (1852–1916) was awarded the 1904 Chemistry Prize "for the discovery of gaseous, indifferent elements in the air and the determination of their place in the periodic system" [40, pp 15–18; 44, pp 23–29], the German Otto Hahn (1879–1968) received the 1944 prize "for his discovery of the fission of heavy nuclei" [40, pp 181–184; 44, pp 272–181], and the Americans Glenn Theodore Seaborg (1912–1999) and Edwin Matisson McMillan (1907–1991) received the 1951 Chemistry Prize "for their discoveries in the chemistry of the transuranium elements" [40, pp 219–231; 44, pp 338–351], all discoveries related to the periodic table. Yet the devisers of the periodic system itself never received this honor.

Although much time had elapsed since the discovery of the system (1869), several chemists who submitted prize nominations considered that its significance had only recently been recognized. In fact, as the discoveries just mentioned clearly demonstrate, research on the system was still taking place, and the system still offered promising fields for research and was a valuable guide for a variety of chemical studies. Of its two primary discoverers the German (Julius) Lothar Meyer (1830–1895) had died before the advent of the prizes; however, the Russian Dmitrii Ivanovich Mendeleev (1834–1907) was nominated in 1905 (three nominations), 1906 (four nominations), and 1907 (two nominations) [65, pp 166–175].

In 1906 one of the five members of the Nobel Committee was so impressed by the work of Frenchman (Ferdinand-Frédéric-) Henri Moissan (1852–1907) that he dissented from the majority's choice of Mendeleev and proposed Moissan instead. He denied that the significance of the periodic system had only recently been fully recognized [25, p 302]:

> The system has in fact been lectured on from all the chairs of chemistry in the world and treated in all textbooks as something which, in spite of its imperfections, has its firm foundations in nature herself.

He argued that it was Cannizzaro's work that had made Mendeleev's system possible and that it would not be just [25, p 302]

> to award the Nobel Prize to the inventor of the periodic system when the man who laid the solid foundation of the determination of the atomic weights on which the periodic system rests, is still unrewarded.

When the question was considered by the Chemistry Committee, four of the ten members agreed with this evaluation, and one abstained. Thus Moissan received five votes and Mendeleev received four votes, and Moissan was awarded the 1906 prize "for his research on the isolation of the element fluorine and for placing at the service of science the electric furnace which bears his name" [40, pp 24-27; 44, pp 35-41]. This was the last opportunity for Mendeleev to receive the prize, for he died on February 2, 1907. It is ironic that on formal grounds the prize was denied to the discoverer of the cornerstone of modern chemistry. In Westgren's view, "Had the Nobel Prize existed in the 1870s and 1880s, he would certainly have received it" [25, p 303].

As is well known, the discovery of organic free radicals in 1900 by the Russian-born American Moses Gomberg (1866–1947) led to numerous studies that have enriched today's theoretical, experimental, and industrial chemistry [67, 68]. Yet he failed to receive the Chemistry Prize for many reasons based on the Nobel statutes and competing claims, but apparently because "the committee did not consider the discovery of free radicals important enough for a Nobel Prize" [69].

The Austrian physicist Lise Meitner (1878–1968) was nominated for the 1937 Physics Prize by Max von Laue and Werner Heisenberg [65, pp 150–155] and for the Chemistry Prize once each in 1924, 1929, 1930, 1933, and 1934 and twice each in 1925, 1936, and 1937 [65, pp 228–235, 248–255, 264–271, 276–283]. As Otto Hahn's three-decades-long collaborator, she played a prominent role in the classic *Naturwissenschaften* article of January 6, 1939, on the nuclear fission of uranium authored by Hahn and fellow German chemist Fritz Strassmann (1902–1980) that ushered in the Atomic Age. Although she had converted from Judaism to Evangelical Protestantism, after the German annexation (*Anschluss*) of Austria in 1938 she was considered non-Aryan (*nichtarisch*) and was forced to flee Germany [70, 71].

The racial policies that had driven Meitner from Germany made it impossible for her to be part of Hahn and Strassmann's publication and dangerous for Hahn to acknowledge their continuing collaboration. Yet, when Hahn accepted the 1944 Nobel Chemistry Prize in December, 1946—after the demise of the Third Reich—he still did not give her adequate credit. To the end of his life he insisted that the obviously interdisciplinary discovery relied on chemistry alone and that Meitner and physics had nothing to do with it—except to prevent it from occurring earlier! On the contrary, Meitner was the one who proposed the experiment that demonstrated that their decomposition product, which Hahn had supposed to be radium, was actually barium, thus showing that fission had occurred. According to Sime, Meitner suffered from "a persistent double exclusion" of women scientists—of their work from both the historical and scientific records [70].

Another scientist who, in my opinion, is worthy of a Nobel Prize, is American chemist Martin David Kamen (b. 1913), who, with coworker Samuel Ruben (1913–1943) discovered carbon-14 on February 27, 1940 [72–75]. Because of Ruben's concern with obtaining tenure, Kamen permitted his friend to be senior author on their article [72], and therefore Kamen's contribution to one of the major discoveries in nuclear chemistry was minimized. American chemist Willard Frank Libby (1908–1980) received the 1960 Chemistry Prize "for his method of using carbon-14 as a measurer of time in archæology, geology, geophysics, and other sciences" [9, p 320; 40, pp 296-300; 44, pp 419-421]. One of his nominators characterized his work as follows [9, p 320]:

> Seldom has a single discovery in chemistry had such an impact on the thinking in so many fields of human endeavour. Seldom has a single discovery generated such wide public interest.

Still, unfortunately, Kamen, the actual codiscoverer of the carbon-14 used by Libby, was never nominated for the prize during the period for which this information is available. Ruben's premature death in 1943 in a laboratory accident involving phosgene precluded a joint award to the pair, but the oversight could be rectified by awarding Kamen the prize in his own right for his discovery of carbon-14 and his subsequent pioneering research on biochemical mechanisms.

Another chemist that I think should have been considered for the Chemistry Prize is British-born chemist and Professor Emeritus at the University of California, Berkeley Neil Bartlett (b. 1932) [76, 77]. For many years the noble gases (formerly inert gases), which constitute a transition group in the periodic table, being neither electropositive nor electronegative but neutral, were believed to have no tendency to gain or lose electrons. The stability of the electron octet and the inertness of the noble gases brilliantly correlated and explained the chemical bonding, valence, and reactivity of the elements, was an integral part of every introductory chemistry course, and was virtually raised to the level of a dogma in chemistry and physics.

Among chemical educators of my generation a standing question–answer joke was: Q.: What is the shortest book in the world? A.: "The Chemistry of the Inert Gases." A related variant was a book with that title consisting only of blank pages. Today such books run to several hundreds of pages with a commensurate number of references to research articles. By 1970 an entire volume of *Gmelins Handbuch der anorganischen Chemie*, and by 1978 a book-length bibliography covering the period 1962–1976 had been devoted to the chemistry of a group of elements that not much earlier were thought to have no chemistry at all.

Neil Bartlett's unexpected synthesis of xenon hexafluoroplatinate(V), $XePtF_6$ [78], revolutionized chemistry, opened a new field of research, and forced chemists and chemical educators everywhere to revise their thinking radically. He had succeeded in preparing a compound of a noble gas where others, including 1906 Nobel chemistry laureate and discoverer of fluorine Henri Moissan, had failed.

I had first learned of Bartlett's discovery at a conference on Advances in the Chemistry of Coordination Compounds at the Ohio State University in Columbus in July, 1962. Someone excitedly interrupted one of the lectures to announce that a young (not quite 30) and comparatively unknown lecturer at the university of British Columbia, famed as having the most beautiful campus in North America, had prepared a compound of the inert gas xenon. Faced with news that one of chemistry's most cherished assumptions had been broken, I had assumed that the entire story was a joke (After all, university chemists, especially when away from their academic home grounds, have been known to take delight in foisting all manner of scientific pranks on their unsuspecting colleagues). The joke, however, was on me when I returned to Fresno and read with much embarrassment of the discovery in that week's *Chemical & Engineering News*. So much for our traditional, idealistic view of ourselves as searchers for truth who regard our scientific beliefs not as absolute truths but as tentative hypotheses, which we are prepared to abandon or modify in the light of new discoveries!

The reader may have his or her favorites for chemists who have been worthy of the Nobel Prize but who were passed over in favor of others. Two more of my candidates are the Americans Gilbert Newton ("G. N.") Lewis (1875–1946) [79] and Henry Eyring (1901–1981) [80]. Lewis was well known for his work on thermodynamics [81] and the free energies of compounds, the first satisfactory theory of the nonpolar (covalent) bond (1916), the shared electron pair and the electron theory of chemical structure [82], and his eponymous concept of acids and bases as electron-pair acceptors and donors, respectively. Without his contributions, the award of the prize to several later chemists would be unthinkable. He was nominated for the prize in at least eleven different years—once each in 1922, 1925, 1926, 1930, and 1931; three times each in 1924 (no prize awarded), 1934 [83], and 1935 [84]; five times each in 1932 [85] and 1933 (no prize awarded); and eight times in 1929 [65, pp 222–225, 228–240, 248–275; 86]. Perhaps, had he not died while working in his laboratory on March 23, 1946, he might eventually have won the prize.

Eyring's theory of absolute reaction rates is one of the most important developments of 20th-century chemistry, and several other chemists later received the prize for work based on it. His failure to receive the prize was a matter of surprise to many chemists.

Other Criticisms of the Prizes

Scholars in various fields have carried out studies of the prizes [87]. Elisabeth Crawford [88], a sociologist and historian of science who has carried out research in the Nobel Archives since they were first opened to scholars in 1974, has criticized the awards on a number of grounds, such as the neglect of entire fields not provided in Nobel's will, the priority assigned to experimental investigations, the advanced age of some of the laureates [89], and the influence of politics and culture, in addition to science, on the prizes. Others, including John Maddox, former editor of the journal *Nature* [90], have called for reform in the selection process.

The award of the prize, especially to younger scientists, has exerted profound effects on their careers, not all of which are positive [91]. Laureates suddenly have their opinions sought after, they can lobby for various causes [92], and they can even have their sperm preserved for eugenics projects [93].

Since 1991 annual "Ig Nobel" prizes, spoofing the actual awards and intending to demonstrate that scientists have a sense of humor, have been presented at Harvard University. In general, these have been accepted with good grace by the scientific community, but in 1966 Robert May, the British government's chief science adviser and obviously a man with little sense of humor, warned that such ridicule could be counterproductive [94].

As we have seen, according to Nobel's will, "no consideration whatever shall be given to the nationality of the candidates, but…the most worthy shall receive the prize, whether he be a Scandinavian or not" [9, p x-xi]. For the chemistry award, the one with which I am most familiar, before World War II the laureates were primarily Europeans, with Germans predominating, followed by Britons and Frenchmen. Since 1946, laureates from the United States predominate, with as many as from all of Europe combined. Unfortunately, a marked under-representation of women shows a definite gender bias. During a century of prizes, only three of the 134 laureates were women—Marie Curie (1911), her daughter Irène Joliot-Curie (1935), and Dorothy Crowfoot Hodgkin (1964) of England [44]. Despite the increasing role of women in chemistry, no woman has received the award during the past 36 years (more than one-third of a century). Fortunately, a solitary showcase dedicated to the question of the reasons for so few female Nobel laureates at the Nobel Centennial Exhibition [47] may help address and rectify this imbalance.

The Nobel Centennial

Various activities have taken place in connection with the Nobel Centennial [1; 95–103]. On November 9, 2000 a Nobel Centennial Symposium titled "Motivations for Research: Contexts, Impacts, and Change" was held at the Chemical Heritage Foundation in Philadelphia, PA [97, 98]. The meeting featured a panel of six Nobel Chemistry laureates—Dudley Robert Herschbach (b. 1932, awarded 1986), Roald Hoffmann (b. 1937, awarded 1981), Jerome Karle (b. 1918, awarded 1985), Rudolph A. Marcus (b. 1923, awarded 1992), George Andrew Olah (awarded 1994), and Max Ferdinand Perutz (b. 1914, awarded 1962), as well as a performance of selections from Carl Djerassi and Roald Hoffmann's play "Oxygen" [104].

An exhibition, "Nobel Voices: Celebrating 100 Years of the Nobel Prize," was opened on April 26, 2001 by three Nobel laureates—Roald Hoffmann (Chemistry, 1981), Phillip A. Sharp (Physiology or Medicine, 1993), and Nicolas de Torrente representing Doctors Without Borders (Peace, 1999)—at the Smithsonian's National Museum of American History in Washington, DC, where it remained until October 30, 2001 [100].

The Nobel anniversary year, officially named the "Nobel Prize Centennial 1901–2001" and organized by the Nobel Foundation, featured a number of special events. On April 1, 2001, "Cultures of Creativity: The Centennial Exhibition of the Nobel Prize" [47, 48], the first major Nobel exhibition ever mounted in Sweden, opened at the Old Stock Exchange (*Borshuset*) in Stockholm's Old Town (*Gamla Stan*). Produced by the Nobel Museum on behalf of the Nobel Foundation, it is on display until 2004, when it will be moved into a museum building of its own. A portion of the exhibit honors all the 719 Nobel laureates through the year 2000. On August 8, 2001, a copy of the exhibition was inaugurated at the Norwegian Folk Museum in Oslo where it was on display for the rest of the year. This traveling copy of the exhibition will then embark on a world tour, beginning in March, 2002, in Tokyo [1, 95, 96].

In 1994 the Internet was first used to announce the awarding of the Nobel Prizes, and in 1995 the Nobel web site was created. It has been upgraded to create a virtual museum of science and culture [101]. In 2000, in connection with the centenary of the Nobel Foundation's establishment, it was formally inaugurated as the "Nobel e-Museum" [101–103], which is now so up to date that at the moment of the annual Nobel Prize announcement detailed information on the new laureates appears instantaneously of the Internet. As part of the Centennial Celebration several new sections of the museum have been introduced, such as the "Wallenberg Young Scholars Program" and "Science & Technology" [1].

All living laureates were invited to participate in a Centennial Week in December, 2001 [1]. The week began with a University Program (December 4–7) of visits by laureates to some twenty Swedish and Norwegian institutions of higher education featuring lectures and discussions and culminated in festivities (concert, reception, banquet, etc.) on December 10 in Stockholm and Oslo. Various pre-2001 laureates participated in the Nobel Foundation's Centennial Symposia held for each of the six prize fields: Physics (December 4–7, Göteborgs Universitet and Chalmers Tekniska Högskola, Göteborg); Chemistry (December 4–7, Södergarn's Education Center, Lidingö); Physiology or Medicine (December 6–8, Karolinska Institutet, Stockholm); Literature (December 4–5, Swedish Academy, Stockholm); Peace (December 6–8, Norwegian Nobel Committee, Oslo); and Economics (Grand Hotel, Saltsjöbaden) [1].

An unusually large number of American laureates live in California. On October 23–27, 2001, a California Nobel Prize Centennial Celebration, featuring a symposium program and an exhibition took place to honor them [105]. It was jointly organized by Stanford University; the University of California, Berkeley; the California Institute of Technology; and the University of California, Los Angeles; along with the Swedish Consulates General in San Francisco and Los Angeles [1].

Centennial Stamp Issues

The first stamps (a set of three) portraying Alfred Nobel were issued by Sweden in 1946, and beginning with 1961 Sweden began to issue an annual series of stamps showing Nobel laureates. All Nobel stamps and first day covers issued since 1961 can be viewed on the Nobel Stamps Web site [106]. In 1988 Foil Miller and I wrote an article on Alfred

Nobel and the Nobel Prizes featuring a number of pertinent postage stamps [11], and in 1990 I wrote a series of three articles on Nobel Chemistry laureates (1901–1988) and their depictions on stamps [107]. Stamps depicting Nobel laureates and Nobel-related items in full color can be found in two beautiful, relatively recent books [108, 109]. In connection with the Nobel Centennial, Sweden Post and the United States Postal Service had a joint issue on March 22, 2001 [1]. The 34-cent U.S. stamp and its Swedish counterpart show Nobel and two of the Nobel medals. The Swedish issue is one of a booklet of four 8-kronor stamps. The other three stamps show the reverse sides of the Nobel medals. Stamps featuring Nobel Peace Prize motifs were issued by Sweden (August 16, 2001) and Norway (September 14, 2001). Centennial stamps have also been issued by several other countries, including Vietnam (January 27, 2001), Monaco (September 3, 2001), and Great Britain (October 2, 2001).

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