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# Nobel prize laureates for chemistry in the period 2000-2021

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## ABSTRACT

The Nobel Prize in Chemistry has a long history since 1901. There were significant changes and discoveries in chemistry in the previous period, especially intensified in the period 2000-2021. There was the development of new scientific disciplines in chemistry, some of which became completely independent. Also, scientific discoveries are increasingly multidisciplinary and the result of the work of large scientific teams. However, all this is not accompanied by an increase in the number of areas for which the Nobel Prize is awarded. The classification of scientific achievements into one of the six areas for which the Nobel Prize is awarded is increasingly tricky due to their complexity and multidisciplinarity. In the period 2000-2021, the largest number of Nobel Prizes have been awarded for research in the field of biochemistry (11), organic synthesis (4), development of new methods and materials (4), and others (3). All this indicates the dominance of research in biochemistry and life sciences and its independence, which is not adequately accompanied by changes in the structure and areas for which the Nobel Prizes are awarded. In the near future, the Nobel Committee should consider this issue and harmonize it with modern trends in science.

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## Introduction

It was initially believed that biomolecules could only be formed in living organisms under the influence of the special life force *vis vitalis*. Such a belief caused the slow development of organic chemistry. In 1828, Friedrich Wöhler was the first to synthesize a biomolecule in the laboratory, urea. This moment was the beginning of modern organic chemistry. The discovery of the first enzyme-diastase in 1833 by Anselme Payen is considered the beginning of biochemistry. It is believed that in 1903, the German scientist Carl Neuberg gave science its current name, biochemistry. Since then, biochemistry has progressed rapidly, followed by the awarding of the Nobel Prize in Chemistry for discoveries in biochemistry.

Only three Nobel Prizes in Chemistry were awarded, which were related to discoveries in biochemistry in the first half of the 20th century (Kostic, 2010):

Buchner (1907) for the discovery of sugar fermentation without the presence of yeast cells;

Harden (1929) to investigate the fermentation of sugars and the enzymes involved;

Sumner, Northrop, and Stanley (1946) for the crystallization of enzymes and the isolation of enzymes and viruses in the pure state.

Numerous instrumental methods were developed, such as chromatography, X-ray diffraction, electron microscopy, nuclear magnetic resonance, isotope labeling, and others, which contributed to significant discoveries in biochemistry. Eight Nobel Prizes in Chemistry were awarded for discoveries in biochemistry (1970-1997).

## Nobel prize in the period 2000-2021

The development of modern methods of analysis has enabled the development of biochemistry. Many molecules were analyzed in detail and their activity in the cells themselves at the molecular level. Complex biological systems, metabolic processes, chemical signaling, and neural function were analyzed.

Table 1 shows the winners of the Nobel Prize in Chemistry, discoveries related to biochemistry and life sciences, organic synthesis of new materials and methods.

**Table 1.** Nobel prize laureates for chemistry in the period 2000-2021 (www.nobelprize.org)

| Year | Scientist | Country | Discovery | Field |
|---|---|---|---|---|
| 2000 | Alan J. Heeger | USA | discovery of plastics that conduct electricity | new materials and methods |
| | Alan G. MacDiarmid | USA | | |
| | Shirakawa Hideki | Japan | | |
| 2001 | William S. Knowles | USA | work on chirally catalyzed hydrogenation reactions | organic synthesis |
| | Noyori Ryoji | Japan | | |
| | K. Barry Sharpless | USA | | |
| 2002 | John B. Fenn | USA | development of techniques to identify and analyze proteins and other large molecules | biochemistry and life science |
| | Tanaka Koichi | Japan | | |
| | Kurt Wüthrich | Switzerland | | |
| 2003 | Peter Agre | USA | discoveries regarding water channels and ion channels in cells | biochemistry and life science |
| | Roderick MacKinnon | USA | | |
| 2004 | Aaron Ciechanover | Israel | discovery of ubiquitin-mediated protein degradation | biochemistry and life science |
| | Avram Hershko | Israel | | |
| | Irwin Rose | USA | | |
| 2005 | Yves Chauvin | France | development of the metathesis method in organic synthesis | organic synthesis |
| | Robert H. Grubbs | USA | | |
| | Richard R. Schrock | USA | | |
| 2006 | Roger D. Kornberg | USA | work concerning the molecular basis of eukaryotic transcription | biochemistry and life science |
| 2007 | Gerhard Ertl | Germany | studies of chemical processes on solid surfaces | other |
| 2008 | Martin Chalfie | USA | | |
| | Osamu Shimomura | USA | | |

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|---|---|---|---|---|
| | Roger Y. Tsien | USA | discovery and development of the green fluorescent protein, GFP | biochemistry and life science |
| 2009 | Venkatraman Ramakrishnan | USA | studies of the structure and function of the ribosome | biochemistry and life science |
| | Thomas Steitz | USA | | |
| | Ada Yonath | Israel | | |
| 2010 | Richard F. Heck | USA | development of techniques to synthesize complex carbon molecules | organic synthesis |
| | Negishi Ei-ichi | Japan | | |
| | Suzuki Akira | Japan | | |
| 2011 | Daniel Shechtman | Israel | discovery of quasicrystals | |
| 2012 | Brian K. Kobilka | USA | studies of G-protein-coupled receptors | biochemistry and life science |
| | Robert J. Lefkowitz | USA | | |
| 2013 | Martin Karplus | Austria/USA | development of multiscale models for complex chemical systems | other |
| | Michael Levitt | UK/USA/Israel | | |
| | Arieh Warshel | Israel/USA | | |
| 2014 | Eric Betzig | USA | development of super-resolved fluorescence microscopy | new materials and methods |
| | Stefan W. Hell | Germany | | |
| | William E. Moerner | USA | | |
| 2015 | Tomas Lindahl | Sweden | mechanistic studies of DNA repair | biochemistry and life science |
| | Paul Modrich | USA | | |
| | Aziz Sancar | Turkey/USA | | |
| 2016 | Jean-Pierre Sauvage | France | design and synthesis of molecular machines | biochemistry and life science |
| | J. Fraser Stoddart | UK | | |
| | Bernard Feringa | Netherlands | | |
| 2017 | Jacques Dubochet | Switzerland | | |

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|---|---|---|---|---|
| | Joachim Frank | Germany/USA | development of cryo-electron microscopy for the high-resolution structure determination of biomolecules in solution | new materials and methods |
| | Richard Henderson | UK | | |
| 2018 | Frances Arnold | USA | first directed evolution of enzymes | biochemistry and life science |
| | George P. Smith | USA | development of phage display, a method in which a bacteriophage can be used to evolve new proteins | |
| | Gregory P. Winter | UK | work using the phage display method for the directed evolution of antibodies | |
| 2019 | John B. Goodenough | USA | development of lithium-ion batteries | new materials and methods |
| | M. Stanley Whittingham | UK/USA | | |
| | Yoshino Akira | Japan | | |
| 2020 | Emmanuelle Charpentier | France | development of a method for genome editing | biochemistry and life science |
| | Jennifer Doudna | USA | | |
| 2021 | Benjamin List | Germany | development of asymmetric organocatalysis | organic synthesis |
| | David W.C. MacMillan | UK/USA | | |

The fact is that since the 1970s, more and more biochemists have won the Nobel Prize in Chemistry, and fewer and fewer have won the Nobel Prize in Physiology or Medicine. In genetics, some discoveries have received awards in physiology or medicine. In contrast, others have received an award for chemistry. Some laureates in chemistry could equally be awarded a prize for physiology or medicine (Lindsten & Ringertz, 2001).

The Nobel Foundation and the Royal Swedish Academy of Sciences gradually changed the character and function of the Nobel Prize in Chemistry. Eleven of the last 22 Nobel Prizes in Chemistry have been awarded for biochemistry and molecular biology achievements.

When writing his will, Alfred Nobel could not have imagined the incredibly rapid development of science in the coming period. Although he did not favor the sciences for which the Nobel Prize would be awarded, Nobel may have considered chemistry the most important. Chemistry was his profession, and chemistry brought him the wealth that enabled the formation of this foundation (Kauffman, 2001).

Are life sciences and chemistry two parts of the same discipline? If so, then the temporal characteristics of the Nobel Prize in Chemistry favoring the life sciences would reflect the reshaping of science. The interdisciplinary nature of much of today's research further disrupts all sharp divisions within the boundaries of rewards (Szell et al., 2018).

Ambiguity and flexibility in setting individual Nobel Prizes within various disciplines go back long. There is a historical record of inconsistent awarding prizes by Nobel Prize-winning bodies.

Are chemistry and biochemistry one discipline so that the achievements in both are appropriately rewarded with the same Nobel Prize, the Nobel Prize in Chemistry? If so, why are so many achievements in biochemistry in the first 60 years awarded the Nobel Prize in Physiology or Medicine?

Despite early points of contact, biochemistry has been constituted since 1920 as a new discipline and profession with specialized journals.

The differentiation of biochemistry from mainstream chemistry does not imply the disappearance of a fundamental aspect of chemistry in biochemistry but rather an evolution on the path of specialization of both disciplines with some points of contact. In the past, biochemistry used scientists and methods from chemistry to later develop its methodologies and its own research goals.

So, in the period 2000-2021, 11 Nobel Prizes have been awarded for research in biochemistry, with the Nobel Prize for 2018 being awarded to three scientists for three different types of research in the field of biochemistry.

In 2000-2021, four Nobel Prizes in Chemistry for Organic Synthesis were awarded.

Research in organic synthesis must continue to keep in step with the need to synthesize increasingly complex target molecules and the need to have synthetic methods characterized by greater ease and efficiency at our disposal. These fundamental exercises, coupled with the many

avenues available for applying organic synthesis, will continue to foster creative works in this area throughout the 21st century.

The Nobel Prizes for the discovery of modern materials and instrumental methods were also awarded: discovery of plastics that conduct electricity, development of super-resolved fluorescence microscopy, development of cryo-electron microscopy for the high-resolution structure determination of biomolecules in solution, development of lithium-ion batteries.

Other discoveries are from other fields of chemistry: studies of chemical processes on solid surfaces discovery of quasicrystals.

Despite the growing interdisciplinarity of research, the Nobel Prize maintains the traditional disciplinary categorization of science.

The interdisciplinary nature of the award is best represented at the Nobel Prize in Chemistry, which was awarded in 2017-the development of cryo-electron microscopy for the high-resolution structure determination of biomolecules in solution. The physical technique was developed with the help of chemistry and was applied to study biomolecules. This indicates that the barriers in question should not hinder the development of science. However, it should be understood that the most revolutionary discoveries in the period 2000-2021 are multidisciplinary and take place in entirely new areas that Nobel could not have imagined developing (Charlton, 2007).

It can also be noticed that the average interval between announcing the discovery and awarding the Nobel Prize is growing, and thus the average age of the laureates. Because of that rule, many great scientists never won the Nobel Prize, even though they were nominated. Since the Nobel Prize cannot be awarded posthumously, it discourages many sciences and disavows the Nobel Prize (Fortunato, 2014).

Nevertheless, one important thing has changed: research disciplines that were not previously linked are now beginning to overlap and merge, and physicists, chemists, biologists, engineers, medics, computer scientists, and mathematicians are solving complex contemporary scientific problems together. One of these areas that are evolving at a rapid pace at the beginning of the 21st century is quantum biology - where quantum physicists, together with molecular biologists, are trying to explain numerous unknown and obscure phenomena in living cells. Over the past few decades, the Nobel Prize program has been slowly but steadily modified in a transparent and non-transparent manner. A transparent change is the establishment of the Nobel

Prize in Economics. The non-transparent change is that the Nobel Prize in Chemistry is transformed into the Nobel Prize in Biochemistry and Life Sciences. A detailed study includes evidence that the disciplines of chemistry and biochemistry cover different and generally scientifically unrelated fields today. An analysis of the Nobel Prizes in Chemistry in the period 2000-2021 encourages the Nobel Committee's program to monitor processes and changes in modern science in a transparent manner (Seeman & Restrepo, 2020).

So, if scientific research is increasingly interdisciplinary, isn't it time for the Nobel Prizes to follow their example and better reflect this trend? The Commission could introduce new categories and change them each year. Maybe one year, it will award the Nobel Prize for astrobiology, materials science, and geophysics, the following year for nanochemistry, artificial intelligence, and quantum biology. The boundaries between the sciences are being erased. Why not just reward the best research? This is not a new idea; physicists and biologists have collaborated fruitfully in the past. Long ago, in 1962, Crick (physicist) and Watson (biologist) were awarded for their discovery of the molecular structure of DNA, which helped solve one of the most important of all biological riddles (https://www.theguardian.com/commentisfree/2012/oct/08/nobel-prizes-need-shakeup)?

The desire to anticipate discoveries permeates almost all aspects of modern science, from individual scientists to publishers, from funding agencies to employment committees. A new and interdisciplinary field of "science of science" is emerging studies of the predictability of scientific discovery and its potential positive and negative impact on the scientific community (Clauset et al., 2017).

## Conclusion

An analysis of the Nobel Prizes in Chemistry in the period 2000-2021 indicates that the largest number of prizes in this field are awarded for discoveries in biochemistry. The Nobel Prize in Chemistry is increasingly becoming the Nobel Prize in Biochemistry and Life Sciences. Suppose we extend this analysis to other scientific branches. In that case, similar results will be obtained because scientific branches are increasingly intertwined, and scientific disciplines that could not be assumed to appear and develop to that extent are formed. The fact is that modern research is very complex and has a multidisciplinary character. More and more researchers dealing

with various scientific branches and disciplines participate in them. All this indicates the need to transform the Nobel Prize in Chemistry. It is necessary to erase the strict boundaries between the scientific branches for which the Nobel Prizes have been awarded so far, increase the number of scientists awarded the Nobel Prize, follow modern scientific research, and reward the most significant scientific achievements each year. This would contribute to the tremendous enthusiasm of scientists and would give a great incentive for even faster development of science.

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## Conflict-of-Interest Statement

None.

## References

Charlton, B. G. (2007). Why there should be more science Nobel prizes and laureates – And why proportionate credit should be awarded to institutions. Medical Hypotheses, 68(3) 471-473. doi: 10.1016/j.mehy.2006.11.003.

Clauset, A., Larremore, D.B., & Sinatra, R. (2017). Data-driven predictions in the science of science. Science, 355 (6324) 477-480. doi: 10.1126/science.aal4217

Fortunato, S. (2014). Growing time lag threatens Nobels. Nature, 508, 186. https://doi.org/10.1038/508186a

https://www.theguardian.com/commentisfree/2012/oct/08/nobel-prizes-need-shakeup

Kauffman, G.B. (2001). The Nobel centennial 1901–2001. The Chemical Educator, 6, 370-384. doi: 10.1007/s00897010520a

Kostic, D. (2010). Nobelove nagrade u hemiji. PMF Niš (in Serbian).

Lindsten, J., & Ringertz, N. (2001). The Nobel prize in physiology or medicine. In A. W. Levinovitz, N. Ringertz (Eds.), The Nobel prize. The first 100 years (pp. 109-127). Imperial College Press/World Scientific: NJ/London.

Seeman, J.I., & Restrepo, G. (2020). The mutation of the "Nobel prize in chemistry" into the "Nobel prize in chemistry or life sciences": several decades of transparent and opaque evidence of change within the Nobel prize program. Angewandte Chemie, 59(8), 2942-2961. doi:10.1002/anie.201906266

Szell, M., Ma, Y., & Sinatra, R. (2018). A Nobel opportunity for interdisciplinarity. Nature Physics, 14, 1075-1078. doi: 10.1038/s41567-018-0314-6

www.nobelprize.org