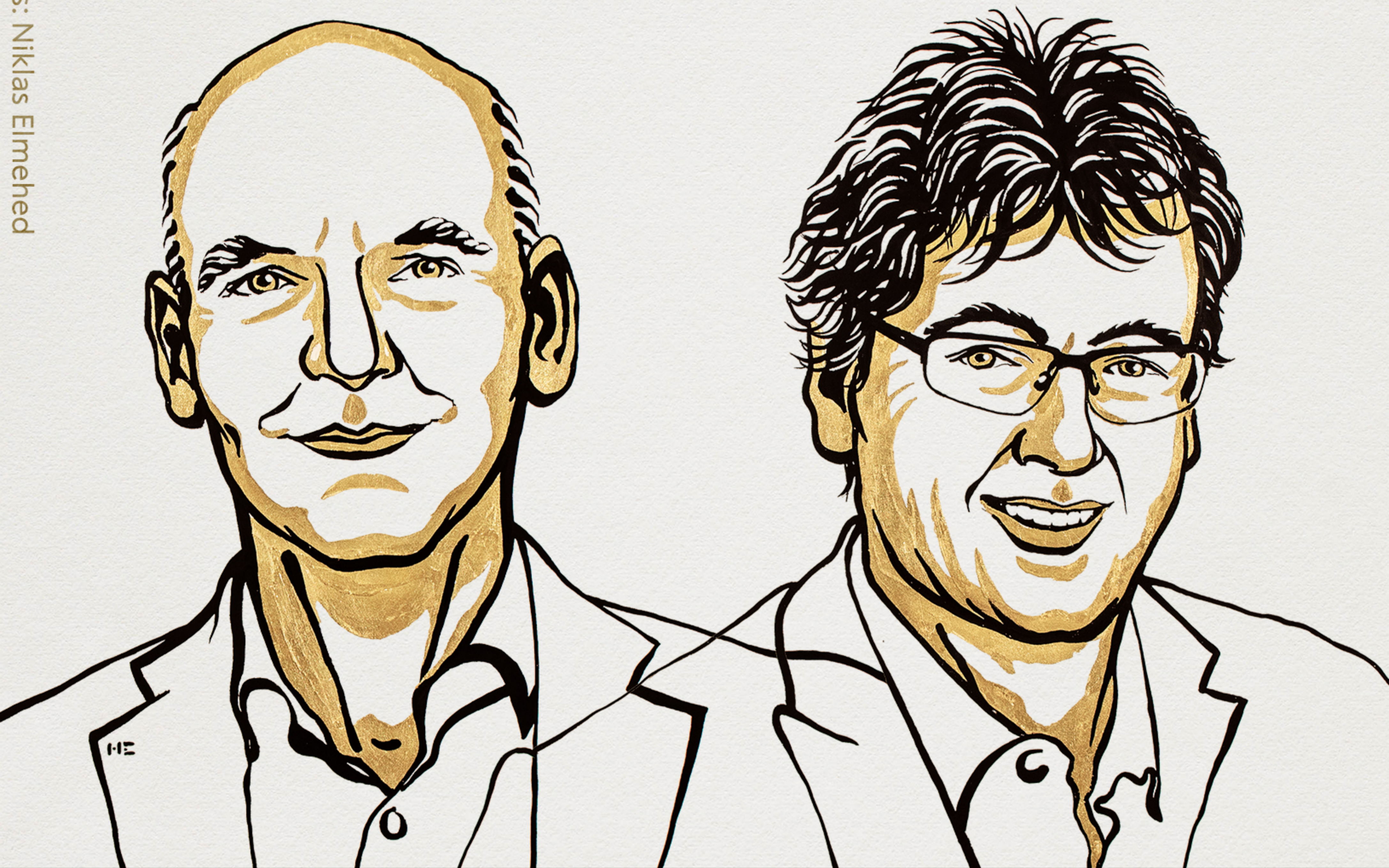


# THE NOBEL PRIZE IN CHEMISTRY 2021

Illustrations: Niklas Elmehed



Benjamin List

David W.C. MacMillan

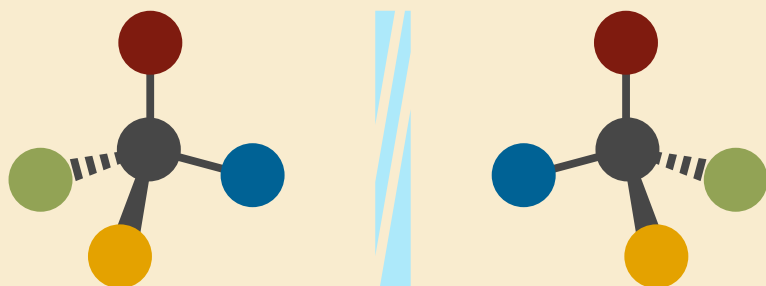
"for the development  
of asymmetric organocatalysis"

THE ROYAL SWEDISH ACADEMY OF SCIENCES

# 2021 NOBEL PRIZE IN CHEMISTRY



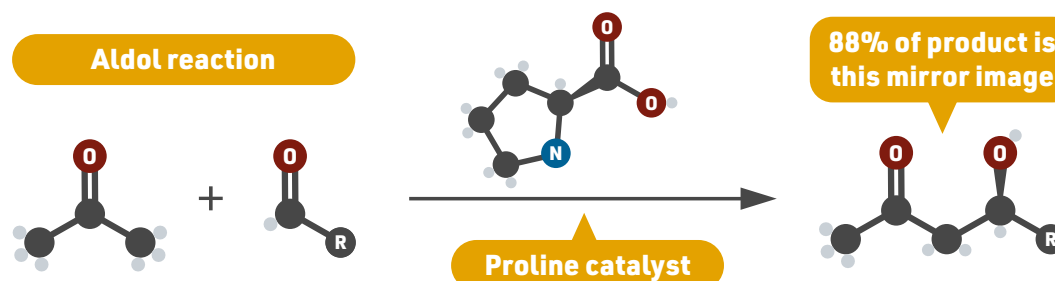
Awarded jointly to **Benjamin List** and **David W.C. MacMillan** for their development of a new type of catalysis, asymmetric organocatalysis, a precise new tool for molecular construction.



Mirror image molecules (enantiomers)

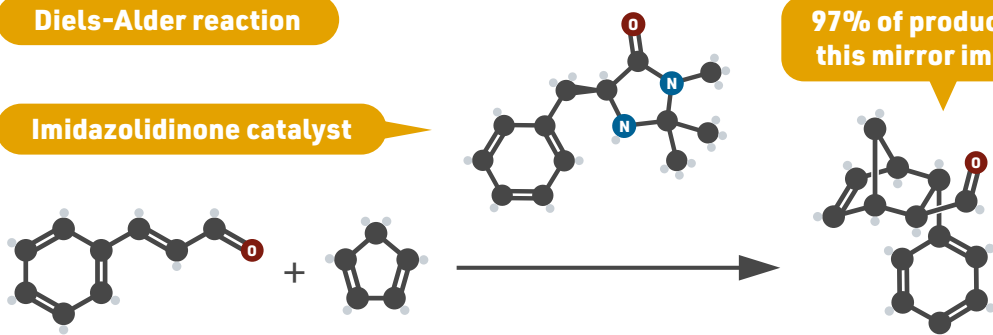
Molecules can exist in mirror image forms with different properties. To make medicines and other compounds we often want just one of these forms. Catalysts, substances that speed up reactions, can help. Nature's catalysts, enzymes, build specific mirror image molecules all the time, but have complicated structures. Metal catalysts can do the job but are sensitive to air and moisture, and sometimes harmful to the environment.

**Benjamin List** wondered if the single amino acids which build up enzymes could catalyse a reaction on their own. Knowing of previous research on the amino acid proline acting as a catalyst, he used it to catalyse an aldol reaction and found it was efficient – and also formed one mirror image of the product much more often than the other.



## Diels-Alder reaction

### Imidazolidinone catalyst



**David MacMillan** tried to develop alternatives to metal catalysts using organic molecules. He identified an imidazolidinone molecule which could catalyse a carbon-carbon bond forming reaction and produced mainly one mirror image of the product. He coined the term 'organocatalysis' for the concept of catalysing reactions using small organic molecules.



Cheaper to use



Environmentally friendly



More efficient

## WHY DOES THIS RESEARCH MATTER?

The winners, along with other researchers, have since designed many more organic molecule catalysts. They are cheap, environmentally friendly, and can make specific mirror images of molecules. They can be used one after another for different reaction steps, improving the efficiency of molecule-making.

Nobel Prize in Chemistry press release: <https://www.nobelprize.org/prizes/chemistry/2021/press-release/>

# The Nobel Prize in Chemistry 2021

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Chemistry 2021 to

## Benjamin List

Max-Planck-Institut für Kohlenforschung,  
Mülheim an der Ruhr, Germany

## David W.C. MacMillan

Princeton University, USA

*“for the development of asymmetric organocatalysis”*

## An ingenious tool for building molecules

**Building molecules is a difficult art. Benjamin List and David MacMillan are awarded the Nobel Prize in Chemistry 2021 for their development of a precise new tool for molecular construction: organocatalysis. This has had a great impact on pharmaceutical research, and has made chemistry greener.**

Many research areas and industries are dependent on chemists' ability to construct molecules that can form elastic and durable materials, store energy in batteries or inhibit the progression of diseases. This work requires *catalysts*, which are substances that control and accelerate chemical reactions, without becoming part of the final product. For example, catalysts in cars transform toxic substances in exhaust fumes to harmless molecules. Our bodies also contain thousands of catalysts in the form of enzymes, which chisel out the molecules necessary for life.

Catalysts are thus fundamental tools for chemists, but researchers long believed that there were, in principle, just two types of catalysts available: metals and enzymes.

**Benjamin List** and **David MacMillan** are awarded the Nobel Prize in Chemistry 2021 because in 2000 they, independent of each other, developed a third type of catalyst. It is called *asymmetric organocatalysis* and builds upon small organic molecules.

“This concept for catalysis is as simple as it is ingenious, and the fact is that many people have wondered why we didn't think of it earlier,” says Johan Åqvist, who is chair of the Nobel Committee for Chemistry.

Organic catalysts have a stable framework of carbon atoms, to which more active chemical groups can attach. These often contain common elements such as oxygen, nitrogen, sulphur or phosphorus. This means that these catalysts are both environmentally friendly and cheap to produce.

The rapid expansion in the use of organic catalysts is primarily due to their ability to drive *asymmetric catalysis*. When molecules are being built, situations often occur where two different molecules can form, which – just like our hands – are each other's mirror image. Chemists will often only want one of these, particularly when producing pharmaceuticals.

Organocatalysis has developed at an astounding speed since 2000. Benjamin List and David MacMillan remain leaders in the field, and have shown that organic catalysts can be used to drive multitudes of chemical reactions. Using these reactions, researchers can now more efficiently construct anything from new pharmaceuticals to molecules that can capture light in solar cells. In this way, organocatalysts are bringing the greatest benefit to humankind.

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**Benjamin List**, born 1968 in Frankfurt, Germany. Ph.D. 1997 from Goethe University Frankfurt, Germany. Director of the Max-Planck-Institut für Kohlenforschung, Mülheim an der Ruhr, Germany.

**David W.C. MacMillan**, born 1968 in Bellshill, UK. Ph.D. 1996 from University of California, Irvine, USA. Professor at Princeton University, USA.

**Prize amount:** 10 million Swedish kronor, to be shared equally between the Laureates.

**Further information:** [www.kva.se](http://www.kva.se) and [www.nobelprize.org](http://www.nobelprize.org)

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The Royal Swedish Academy of Sciences, founded in 1739, is an independent organisation whose overall objective is to promote the sciences and strengthen their influence in society. The Academy takes special responsibility for the natural sciences and mathematics, but endeavours to promote the exchange of ideas between various disciplines.

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