The chemistry prize was shared by Benjamin List, of the Max Planck Institute for Coal Research, in Mülheim an der Ruhr, and David MacMillan, of Princeton University.

Their prizewinning work, published in 2000, was conducted independently, and unknown to each other at the time, but with the same end in mind. This was to break the stranglehold of enzymes and transition metals on the field of catalysis.

Some chemical reactions proceed with alacrity. Most, though—including many that are industrially important—need a helping hand in the form of a catalyst.

Evolution has provided a goodly range of these in the form of enzymes, which are large, complicated and sometimes temperamental protein molecules, but which have the advantage that they can create pure versions of what are known as optical isomers.

These are molecules that have two forms which are mirror images of each other. This is important in the drug industry, for the different versions, known as enantiomers, can have different effects in the body.

Also, if you choose the right enzymes, it is often possible to carry out multi-step reactions in only a few stages.

Transition metals are those in the middle of the periodic table—copper, nickel and iron, for example.

The structures of the electron shells surrounding the nuclei of their atoms are complicated, meaning they are chemically versatile. This is what makes them good catalysts.

Some transition-metal catalysts are the metals themselves. More often, they are small molecules that include a transition-metal atom.

Transition-metal catalysts can be easier to handle than enzymes, but usually fail to distinguish between enantiomers.

Also, transition-metal compounds are frequently toxic, with all the environmental consequences that entails. And multi-step reactions involving them can be long-winded.

Dr List and Dr MacMillan found a way to have the best of both worlds: small-molecule catalysts that have no metal atoms in them, can turn out pure enantiomers, and often simplify multi-step reactions. That has significant industrial implications.

Dr List worked on an enzyme called aldolase A. This catalyses what is known as the aldol reaction, an important way of forging molecular bonds between carbon atoms.

Aldolase A is made of 350 amino acids, the building blocks of proteins, but the bit that does the work consists of only three of these: lysine, glutamic acid and tyrosine. The rest of the enzyme is packaging.

He therefore wondered if he could isolate the enzyme’s active centre and yet preserve its activity. In fact, he did better.

He showed that the aldol reaction can be catalysed by a single amino acid, proline. And, crucially, this retains the enantiomeric purity of the enzyme-mediated reaction.

Dr MacMillan came from the other end of the problem. He wanted to remove the metal (in this case copper) from the catalyst involved in a different process, the Diels–Alder reaction.

This is a way of joining two molecules into a six-carbon ring. One of the reagents contributes four carbon atoms to the ring and the other contributes two.

Six-carbon rings are ubiquitous in organic chemistry, and by putting different side groups onto the reagents a vast variety of them can be turned out.

Dr MacMillan found he could catalyse Diels-Alder reactions using a type of metal-free molecule called an imidazolidinone to activate the two-carbon component, meaning that it combines enthusiastically with its four-carbon compadre.

The result of these two pieces of work is a field called asymmetric organocatalysis (the asymmetric part of the name referring to its ability to generate pure enantiomers), that is now rippling through industrial chemistry.

And, since industrial chemistry, in one form or another, underpins most economic activity, it is also rippling, however invisibly, through life.

诺贝尔化学奖由位于鲁尔河畔米尔海姆州马克斯·普朗克煤炭研究所的本杰明·利斯特和普林斯顿大学的大卫·麦克米伦共享。

他们的获奖作品发表于 2000 年，是独立进行的，当时彼此都不知情，但目的是一致的——为了打破酶和过渡金属在催化领域的束缚。

有些化学反应进行得很快。然而，大多数企业，包括许多在工业领域具有重要地位的企业需要催化剂的帮助。

进化以酶的形式提供了大量的这类物质，这些酶是大型的、复杂的、有时还会变化无常的蛋白质分子，但它们的优点是可以产生被称为光学异构体的纯净版本。

这些分子有两种形式且互为镜像。这在制药行业很重要，因为不同对映体，对人体会产生不同的作用。

此外，如果你选择了正确的酶，通常只需几个阶段就可以进行多步反应。

过渡金属是那些位于元素周期表中间的金属，例如铜、镍和铁。

它们原子核周围的电子壳层的结构很复杂，这意味着它们具有多种化学用途。这就是它们成为良好催化剂的原因。

一些过渡金属催化剂本身就是金属。更常见的是，它们是包含过渡金属原子的小分子。

过渡金属催化剂可能比酶更容易操作，但通常无法区分对映体。

此外，过渡金属化合物通常是有毒的，因此会对环境带来不良影响，而且涉及到它们的多步骤反应可能是冗长的。

利斯特博士和麦克米伦博士找到了一种两全其美的方法：不含金属原子的小分子催化剂，可以生成纯净的对映体，而且通常会简化多步反应。这具有重大的工业意义。

利斯特博士研究了一种名为醛缩酶 A 的酶，这种酶催化所谓的醛缩反应，这是一种在碳原子之间形成分子键的重要方式。

醛缩酶 A 由 350 种氨基酸组成，这些氨基酸是蛋白质的组成成分，但起作用的部分只有三个：赖氨酸、谷氨酸和酪氨酸。剩下的酶是包装的。

因此，他想知道他是否能分离出这种酶的活性中心，同时又能保持它的活性。事实上，他做得比想象中更好。

他证明了羟醛缩化反应可以被一种氨基酸--脯氨酸催化。最重要的是，这保留了酶介导反应的对映体纯度。

麦克米伦博士来自问题的另一端。他想从另一个过程——狄尔斯-阿尔德反应（Diels-Alder reaction）中的催化剂中去除金属（在这种情况下是铜）。

这是一种将两个分子连接成六碳环的方法。其中一种试剂为环贡献了四个碳原子，另一种试剂则贡献了两个碳原子。

六碳环在有机化学中普遍存在，通过在试剂上加入不同的侧基，可以产生多种六碳环。

麦克米伦博士发现，他可以使用一种名为咪唑烷酮的无金属分子来催化狄尔斯-阿尔德反应，以激活双碳成分，这意味着它可以与其四碳化合物结合。

这两项工作的结果是一个被称为不对称有机催化的领域（这个名称的不对称部分指的是它产生纯对映体的能力）现在正席卷工业化学界。

而且，由于工业化学以这样或那样的形式支撑着大多数经济活动，所以也以看不见的方式影响着人们的生活。