Nobel Prize for Physics

Professors Jerome I. Friedman (b. 1930) and Henry W. Kendall (b. 1926), both of the Massachusetts Institute of Technology (MIT), and Richard E. Taylor (b. 1929), of the Stanford Linear Accelerator Center (SLAC), share this year's Nobel Prize in Physics. The citation says that it has been awarded to them **for their pioneering investigations concerning deep inelastic scattering of electrons on protons and bound neutrons, which have been of essential importance for the development of the quark model in particle physics.** The three prize winners were key persons in a research team which in a series of investigations found clear signs that there exists an inner structure in the protons and neutrons of the atomic nucleus. What has become known as the "SLAF-MIT experiment" paved the way for further investigations of the innermost structure of matter.

Ever since the beginning of this century, researchers have studied the inner structure of atoms. Our knowledge has increased successively, among other ways through the discovery (around 1910–1930) of the nucleus of the atom and its nucleons. During the 1950s there arrived on the scene a large number of what were termed "hadrons", whose properties resembled those of nucleons. To reduce these to order, the concept of quarks was introduced, at the beginning of the 1960s. Yet it was impossible to see any traces of quarks in nature until the SLAC-MIT experiment.

The discovery was made when protons and neutrons were illuminated with electron beams from the two-mile-long accelerator at SLAC in California, USA. The inner structure was interpreted to mean that quarks form the fundamental building blocks of protons and neutrons. The electrically neutral "glue" binding the quarks together is called gluons. All matter on earth, consists to more than 99% of quarks with associated gluons. The little that remains is electrons.

The prizewinners' contributions

The work now rewarded was carried out at the end of the 1960s and the beginning of the 1970s. The work was a continuation of earlier investigations in which, using the electron as a probe, the structure of nucleons (protons and neutrons) was studied. Unlike in earlier investigations, electron beams of very high energies were now available, which acted in an "electron microscope" of higher resolution. When the experiments were started no new phenomenon was expected and they were regarded as routine. In fact it was thought that enough was known about the structure of nucleons—a view that proved to be entirely false.

The essence of the SLAC-MIT experiments was to observe how a beam of electrons at high velocities (energy from 4 GeV to 21 GeV) is affected when it is led through a target consisting either of liquid hydrogen or of deuterium. The scattered electrons at angles varying from 6° to 34° were recorded using two large magnetic spectrometers and their energy of the electrons at these angles was measured.

Collaboration between SLAC and MIT started at the beginning of 1967, with the study of so-called elastic scattering against protons (the process e+p−>e+p, in which the electron bounces against the proton as if they were both rubber balls). Similar experiments at lower electron energies had shown that the nucleons behaved like "soft" structures which were only able to scatter the electrons at small angles. The new results from elastic scattering confirmed the earlier measurements. The probability of obtaining a large scattering angle was found to be very small. Following this conventional initial phase, it was decided to have a look also at what was termed inelastic electron scattering, e+p−> e+X, where X is not necessarily a proton. Such processes were known from experiments at lower energies. However, the researchers found, to their amazement, that the probability of deep inelastic scattering—where the incident electron loses a large part of its original direction—was considerably greater than expected. At first they believed that the result was incorrect or misinterpreted. One suspected source of error was the so-called radiation corrections when the incident or departing electron could radiate away part of its energy in the form of light, (which they had not observed). But after careful work it gradually became clear that an inner nucleonic structure, termed hard scattering centres, had been observed. Here was a repetition, although at a deeper level, of one of the most dramatic events in the history of physics, the discovery of the nucleus of the atom by Rutherford on the basis of the experiments by Geiger and Marsden (1909).

The first traces of quarks

The SLAC-MIT experiments became the contemporary counterpart of Geiger and Marsden's experiment. At that time, the scattering of alpha particles at large angles was explained as due to the existence of a 'hard grain'—the atomic nucleus—in the middle of the atom. In the modern version, Rutherford's role was assumed chiefly by the theoreticians James D. Bjorken and Richard P. Feynman. This time, the scattering of electrons at large angles was explained by the existence of 'hard grains'—quarks—in the nucleons. But the results could not be fully explained using quarks alone. The experiments indicated that there were also electrically neutral components in the nucleons. Development was rapid and the neutral components of the nucleons were soon interpreted as gluons, the intermediaries of the strong force. This has launched a new era in the history of physics.

Nobel Prize for Chemistry

This year's Nobel Prize in Chemistry has been awarded to Professor Elias J. Corey, USA, for his important contributions to synthetic organic chemistry. The citation states 'for his development of the theory and methodology of organic synthesis.' His theories and methods have made it possible to produce a large variety of biologically active, complicated natural products, and pharmaceuticals in the laboratory and commercially. Corey's work has also led to new general methods of producing, or synthesising, compounds in much simpler ways.

The background to Elias J. Corey's successes lies in the fact that he has in a strictly logical way developed the principles of what is termed *retrosynthetic analysis*. This involves starting from the planned structure of the molecule one wished to produce, (i.e. the target molecule), and analysing what bonds must be broken, thus simplifying the structure step by step. One then finds that certain fragments are already known and their structures and synthesis already described. After working backwards in this way from the complex to the already known, it is possible to start synthesising the molecule. This method has proved very amenable to "data processing", which has entailed rapid developments in "synthesis planning". Combining this synthesis planning with remarkable creativity, Corey has developed new methods of synthesis. He has produced more than hundred important natural products.

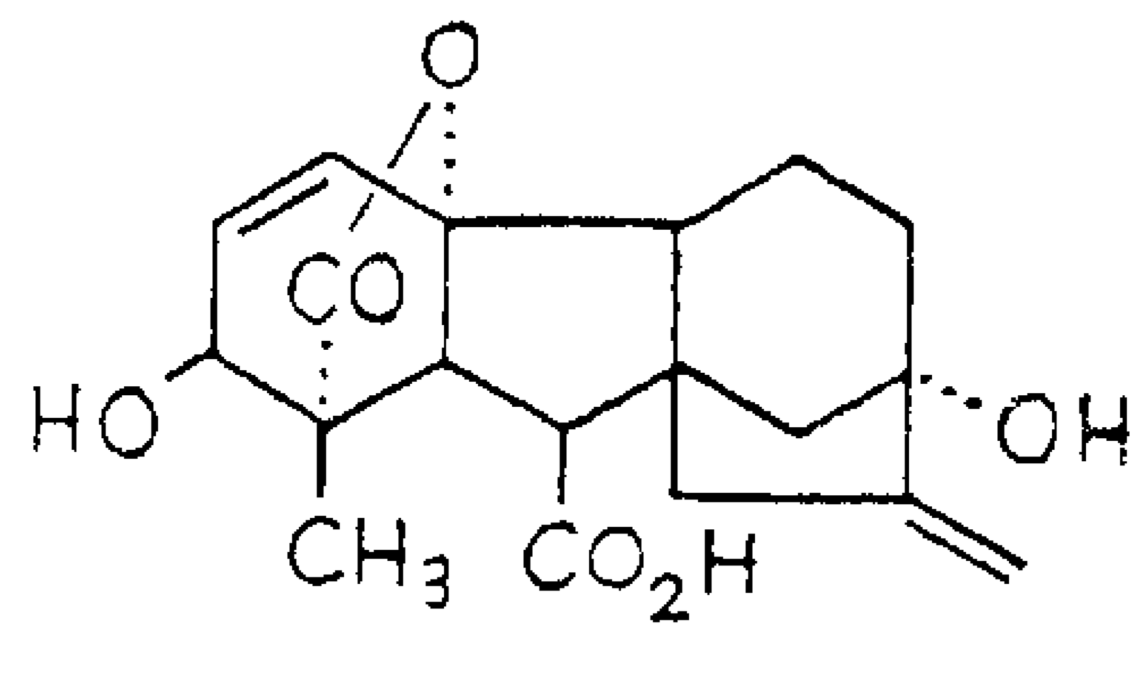
It is understandable that contributions to organic synthesis have often been rewarded with Nobel Prizes in Chemistry. Thus in 1902, only the second year that Nobel Prizes were awarded, the Chemistry Prize went to Emil Fischer for his work on synthesis in sugar and purine chemistry. Adolf von Baeyer received the prize in 1905 in recognition of contributions to the development of the chemical industry through his work on organic dyestuffs. Otto Wallach received the 1910 prize for contributions to the development of the chemical industry. The 1912 prize went to Victor Grignard for his work on organic magnesium compounds, (the Grignard reagents). In 1950 Otto Diels and Kurt Alder shared the Nobel Prize for discovering the preparatively very useful diene synthesis. Robert B. Woodward received the 1965 prize for his brilliant contributions to the development of the art of organic synthesis. In 1979 Herbert C. Brown and Georg Wittig were rewarded for developing boron compounds and phosphorus compounds, respectively, important reagents in organic synthesis.

The synthesis of complicated organic compounds often shows elements of artistic creation, as for example architecture. Many earlier syntheses were performed more or less intuitively, so that their planning was difficult to perceive. Asking a chemist how he came upon precisely the starting materials and reactions that so elegantly led to the desired result would probably be as meaningless as asking Picasso why he painted as he did. The process of synthetic planning has been likened to a game of three-dimensional chess using 40 pieces on each side. Over 35,000 usable methods of synthesis are described in chemical literature, each with its possibilities and its limitations. During the synthesis, moreover, new methods appear which can modify the strategy.

Beginning in the 1960s, Corey (coined the term), and developed the concept of *retrosynthetic analysis*. Starting from the structure of the target molecule, he established rules for how it should be dissected into smaller parts, and what strategic bonds should be broken. In this way, less complicated building blocks were obtained, which could later be assembled extremes. These building blocks were then analysed in the same way until reaching simple compounds whose synthesis was known, or which are even commercially available. Corey showed that strictly logical retrosynthetic analysis was amenable to computer programming. At present synthesis planning with the help of computers is developing rapidly.

Through his brilliant analysis of the theory of organic synthesis, Corey has contributed greatly to complete total syntheses of what was considered, hitherto impossible, naturally occurring, biologically active compounds.

Corey has himself synthesised about a hundred important natural products. In 1978 he produced gibberellic acid(1), which belongs to a class of very important plant hormones of complicated structure. Recently, he has synthesised (+)−ginkgolid(2), which is the active substance in an extract from the ginkgo tree, used as a folk medicine in China. It is used in treatment of blood circulation disturbances in the elderly, and in asthma. Owing to its complicated structure this has been considered to be a



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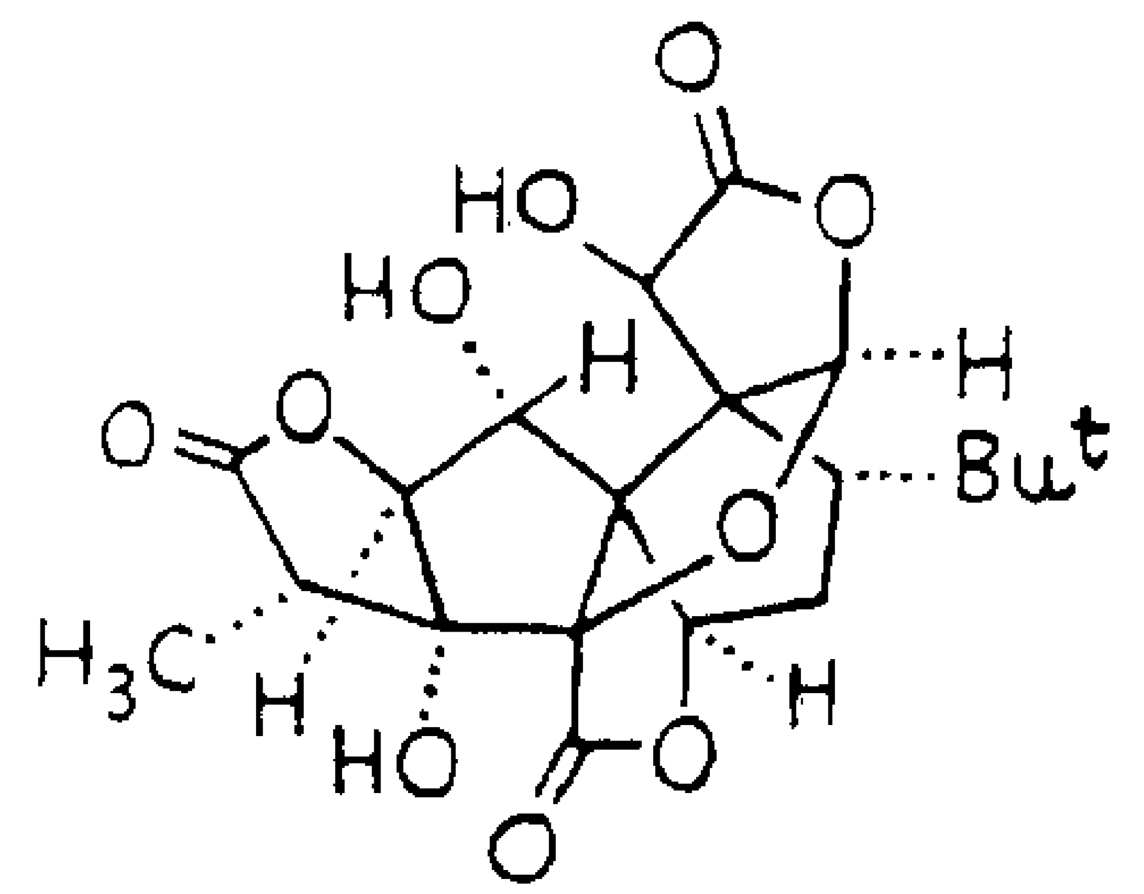

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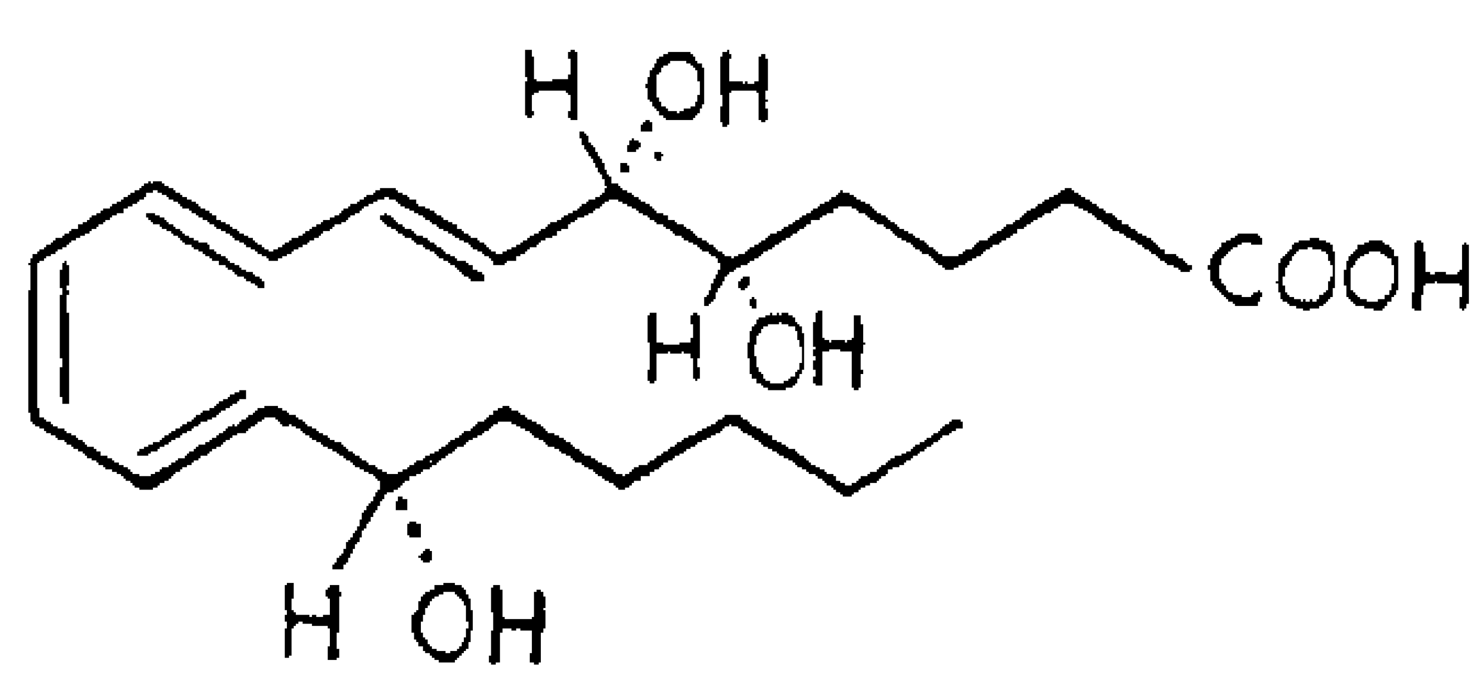
formidable challenge to anyone working in synthetic chemistry. The sales value of this natural product is believed to amount $ 500 million annually!

Corey's most important total syntheses concern eicosanoids such as prostaglandins, prostacyclins, thromboxanes and leucotrienes, which occur naturally in extremely small quantities. Their importance is witnessed by the award of the 1982 Nobel Prize in Physiology or Medicine to Sune Bergstrom, Bengt Samuelsson and John Vane for the discovery of prostaglandins and closely related biologically active substances. These frequently very unstable compounds answer for multifarious and vital regulatory functions of significance for reproduction, blood coagulation, normal and pathological processes in the immune system etc. Corey has, with enormous skill carried out structural determination and total syntheses of a large number of many different types of



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eicosanoids such as prostaglandins and leucotrienes such as lipoxin A(3). It is thanks to Corey's contributions that many of these important pharmaceuticals are commercially available.

To perform the total syntheses successfully, Corey was also obliged to develop some fifty entirely new or considerably improved synthesis reactions of reagents. It is probable that no other chemist has developed such a comprehensive and varied assortment of methods which, often showing the simplicity of genius, have become commonplace in the synthesising laboratory. His systematic use of different types of organometallic reagent has revolutionised recent techniques of synthesis in many respects. He has also in recent years introduced a number of very effective enzyme-like catalysts. These chiral catalysts give only one mirror isomer of the target product, in certain types of synthetically important reaction. The chiral catalysts are simple and easy to recover, and can in some case be used in their own production.

Nobel Prize for Medicine

The 1990 Nobel Prize in medicine will go jointly to Joseph E. Murray of the Brigham and Womens Hospital in Boston and E. Donnal Thomas of the Fred Hutchinson Cancer Center in Seattle for their outstanding clinical work into organ and cell transplantations. The Nobel Committee said that the work of these two doctors gives hope to those tens of thousands of ill people who can be cured or given a decent life when other methods have failed.

Thomas has been successful in grafting bone marrow from one individual to another. Bone-marrow transplantation can cure patients with leukaemia and other blood cancers and some severe blood disorders, who would otherwise die. Patients who survive two and a half years (and 60 per cent do) after the operation have a normal life expectancy.

Murray did the first human kidney transplant between identical twins. He also pioneered kidney transplantation with kidneys obtained from deceased persons. His work has paved the way for transplanting other organs like heart, lung and liver.

Murray was born on 1 April 1919 and was trained as a plastic surgeon. His interest in transplants was kindled during World War II when he grafted skin onto wounded soldiers. In the 1950s he began kidney-transplant experiments on dogs. In 1954 Murray achieved the first successful human kidney transplant, which involved identical twins. He then started experimenting with new drugs to suppress the immune system. Such drugs allowed him to use kidneys from relatives of patients and, later, even from cadavers. Now thousands of patients have kidney transplants each year, and the new kidney survives and thrives for at least ten years in 70 per cent of the patients.

Thomas, born on 5 March 1920, first did bone-marrow transplants in dogs. He used drugs and radiation to suppress the recipient's marrow. Successful transplants in humans are more difficult to achieve. But Thomas persisted, and, learning to match tissue types and using immunosuppressive drugs, achieved the first successful bone-marrow transplant in humans in 1970. Thomas has built the world's largest bone marrow transplant unit at the Fred Hutchinson Cancer Center, where doctors perform 350 transplants a year.

Both Murray's and Thomas' successes have resulted from great improvements in ability to match organs to recipient's tissues so that the new organs are not rejected, and from the use of immunosuppressive drugs.

This year's award has evoked some surprise for being a recognition of clinical work; the Nobel Committee has tended to favour basic scientific research. Transplantations also tend to be a controversial subject on account of their high cost and the ethical and social questions they raise. But none of this can take away the value of the work of Thomas and Murray.

Fields medals 1990

The highest award to which a mathematician can aspire is the Fields medal, an award comparable in many respects to a Nobel prize in the prestige it confers. J. C. Fields, who set up a trust for the gold medals that constitute the award, said that they should be made in recognition of work already done and as an encouragement for further achievements on the part of the recipient. This has been interpreted to mean that the medal should be given to young mathematicians (generally those under the age of 40), a tradition that has been closely followed since the first two medals were awarded in 1936. The Fields medals are given out only every 4 years, at the quadrennial convening of the International Congress of Mathematicians. The medal carries a cash award of $15,000 Canadian. The way medallists are selected has come in for criticism from some mathematicians, as, unlike in the case of Nobel prizes, the names of the committee members who select the Fields medal-winners were not made public. ICM argued that keeping the committee names private eased pressure on them to choose well-known figures. This year, however, the names of the members of the committee, chaired by Prof. Ludwig D. Faddeev, are known.

This year's winners announced at ICM in Kyoto, Japan, include

– Vladimir Drinfeld of the Institute for Low Temperature Physics and Engineering in Kharkov, USSR. Drinfeld's recent work has focused on the theory of quantum groups, a branch of mathematical physics.

– Vaughan Jones of the University of California at Berkeley. He discovered the 'Jones polynomial', an equation that provides the best method to date for helping mathematicians to distinguish knots from one another.

– Shigefumi Mori of Kyoto University in Japan, whose work in algebraic three-dimensional manifolds recently resulted in the extension of classical theory of algebraic surfaces to three dimensions.

– Edward Witten of the Institute for Advanced Study at Princeton. Most recently, Witten has explored the relations between quantum field theory and the differential topology of two and three-dimensional manifolds.