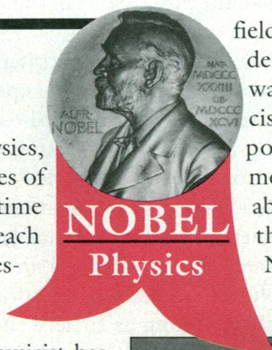
Nobel Prizes '91

There weren't many surprises in this year's crop of Nobel Prizes. Most of the awards had long been expected by insiders in their various fields. Perhaps the biggest shock was that this year, for the first time in recent memory, no American received a hard science prize.

Physics: Untangling Spaghetti



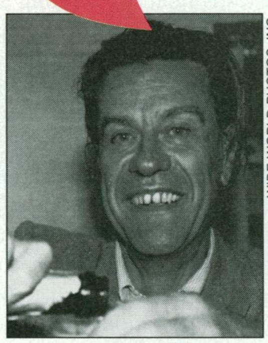
This year's Nobel Prize in physics, given to Pierre-Gilles de Gennes of the Collège de France for a lifetime of varied achievement, should teach young scientists an important lesson: You don't have to tread the beaten path to succeed. Indeed, the French theoretical physicist has made a career of throwing out the rulebook on career moves. Rather than looking for "hot areas" in physics, de Gennes worked in cool regions of his discipline: areas left unexplored by physicists, where no one thought physics could bring results. By plowing ahead in such areas—particularly liquid crystals and polymers—de Gennes has shown that mathematical elegance and order underlie even the "messiest" physical phenomena.

De Gennes, now 58, actually began his career in a fairly conventional way, looking into magnetism and superconductivity. In the 1960s, however, he branched out and began showing the qualities that have made him so successful. To begin with, he chose a subject that had been discovered in the 1920s yet remained barely understood by physicists 40 years later: liquid crystals.

These curious substances can act like a liquid (flowing and disordered) in one direction yet like a crystal (rigid and ordered) in another. That duality comes from their molecular structure, which in the simplest case resembles a series of rodlike molecules floating in a solution. Mechanical or electrical forces can induce a phase change—lining up the rods like logs in a logjam.

Such phase changes provide the key to the ability of liquid crystals to light up the numbers on digital watches and calculators. In a typical display, a phase change triggered by an electric field transforms a region of liquid crystal from transparent to opaque—making the region glow with reflected light. De Gennes, with a French research group he formed, learned to understand and predict these phase changes by applying the mathematical relationships that govern similar transformations in magnetic materials and superconductors.

Having shed reflected light on the murky field of liquid crystals, in about 1970 de Gennes continued his maverick ways by moving into a field physicists thought of as even messier: polymers. Applying physics to polymers, most physicists felt, made about as much sense as predicting the weather armed only with Newton's equations. "De Gennes moved into a field we considered dirt physics, dirt chemistry," says physicist Phil Anderson of Princeton University.



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Pierre-Gilles de Gennes

What made polymer chemistry "dirt chemistry" was that the ordinary rules of physics didn't work for anything as complex and unpredictable as a beaker of melted plastic, which on the molecular level is like a vast tangle of spaghetti. Each strand is a long chain of different repeating units, and before de Gennes their large-scale behavior could be roughly described by chemical laws, but not by the more exacting analysis of physics. De Gennes untangled the physics of polymers, says Anderson, by comparing them to simpler systems he already understood: magnets, superconductors, and liquid crystals. By doing that, he discovered that some mathematical relationships were shared by all these systems.

De Gennes' biggest contribution, according to University of Chicago polymer physicist Thomas Witten, was a mathematical rule to determine the length of the long polymeric chains as a function of their thickness. Before that discovery, no one understood why polymer chains of various sorts grew to the specific lengths they did. De Gennes, explains Witten, calculated the chain length with the same mathematics that determines the size of bubbles in boiling liquids. That stroke of insight led him to apply to polymers a rule known as the "N-vector model."

"A genuine miracle occurred in 1972 when he could attain properties of polymers with the N-vector model," says Eugene Stanley, a polymer physicist from Boston University. "Before, that, there was no way to work with polymers as a physicist." What is more, understanding the small-scale properties of a material often leads to a new ability to predict and control bulk properties, and that's just what de Gennes' N-vector model did for polymers: Knowing the length of individual strands makes it possible to control viscosity and other properties that anyone thinking about applications needs to be able to determine.

In lauding him for these discoveries, de Gennes' colleagues keep coming back to two qualities: his daring in venturing off the beaten track and his desire to know new fields. Chemical engineer William Graessley says, "He looks at problems outside the traditional bounds of physics and [has] brought a lot of fresh insights. His work has had dramatic effects in chemistry, materials science, and chemical engineering."

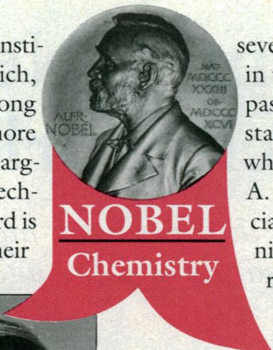
Longtime colleague Philip Pincus of the University of California, Santa Barbara, admits to being baffled by his French colleague's ability to keep abreast of so many different areas. "I know him as well as anybody," he says, "and he never ceases to amaze me. He'll come in and say, 'You know about this thing someone did in 1953'—yet how he learns these things I don't know."

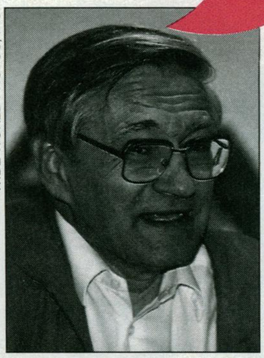
De Gennes, his American colleagues say, prefers going to conferences on topics he knows little about, rather than those in familiar terrain. "What am I going to learn from those?" he would ask Pincus. That insatiable curiosity—coupled with the desire to see unifying principles in disorderly fields—has paid off with science's highest award. ■ FAYE FLAM

Chemistry: A Certain Resonance

Of all the many laboratory techniques, very few provide the basis for even a single Nobel Prize. It's even rarer when a technique is connected with the awarding of two prizes. But that's what happened last Wednesday when the Swiss physical chemist Richard R. Ernst was awarded the prize in chemistry for his work on nuclear magnetic resonance (NMR). The first prize was given to Edward M. Purcell and Felix Bloch in 1952 for discovering the physical phenomenon behind the technique: Certain atomic nuclei that have been knocked out of alignment in a strong magnetic field by a burst of radiation will realign and emit characteristic resonance frequency signals that provide a kind of chemical signature. Indeed, in his prize acceptance lecture, Purcell prophesied that this property might be harnessed for getting molecules to broadcast information about their structures.

From there, Ernst, of the Federal Institute of Technology (ETH) in Zurich, picked up the baton—and ran. Among those who know the field, he gets more credit than anyone else for the ever-enlarging family of NMR-based analytical techniques. One reason for last week's award is that those techniques are well on their way to becoming as central to biochemistry, biology, materials science, and medicine as they have been to chemistry for decades.

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Richard Ernst

When the award was announced, Ernst was on a flight to Columbia University. "It was a great surprise to receive this message above the North Sea," he told *Science* in an interview last Thursday. Ironically, he was on his way to pick up yet another award for his work on NMR: the Louisa Gross Horwitz Prize, which was given to Ernst and ETH colleague Kurt Wüthrich for developing NMR methods capable of revealing the structure and behavior of complex biological molecules.

The basis of all NMR methods lies in the ability of certain atomic nuclei—including hydrogen atoms—to behave like diminutive magnets whose orientations can be changed with radio frequency radiation. When molecules containing such atoms are placed in a strong magnetic field, those nuclei align in the field. Showering the sample with radio frequency bursts kicks the nuclei into different orientations, as prescribed by the laws of quantum mechanics. And that's when the molecules start revealing details about their structures. As the various nuclei in their distinct molecular locations realign with the magnetic field, they emit "resonance frequency" signals that can be detected with a sensitive coil. NMR spectra consist of peaks corresponding to signals from different nuclei in the molecule.

"Compared to other analytic tools, NMR gives you information about the local structure of molecules," often allowing chemists to determine a molecule's overall structure, Ernst said. For example, NMR has has advantages over infrared (IR) spectroscopy, an old analytical standard based on the property of different kinds of chemical bonds to absorb characteristic wavelengths of infrared radiation. IR spectra tell chemists about the presence of chemical groups in samples, but not how those groups arrange themselves in a specific molecular structure.

The Swedish Academy of Sciences cites several pivotal developments in the field of NMR over the past 25 years that bear Ernst's stamp. In the mid-1960s, when he worked with Weston A. Anderson at Varian Associates in Palo Alto, California, the two developed Fourier Transform-NMR, now the basis for tens or hundreds of thousands of standard NMR spectrometers used around the world for studying liquid samples. "Now every time chemists run a reaction, the first thing they do is take some of the product and put into an NMR [spectrometer]," notes John Waugh, a physical chemist at MIT.

That's fine for small molecules. But scientists have been getting ever more adept at making and studying larger and more complex molecules including proteins. But the more complex the molecule, the busier and more chemically ambiguous its NMR spectrum. So in the mid-1970s, Ernst and others found ways of taming data from such samples by using judicially timed pairs of radio pulses, together with mathematical techniques and computers. These "two-dimensional" methods resolve overlapping NMR peaks by separating them into a second dimension. In addition to opening more complex molecules to NMR analysis, these techniques became the basis for a powerful variation on the NMR theme called Magnetic Resonance Imaging (MRI) that physicians now use to noninvasively examine tissues inside patients without using damaging forms of radiation.

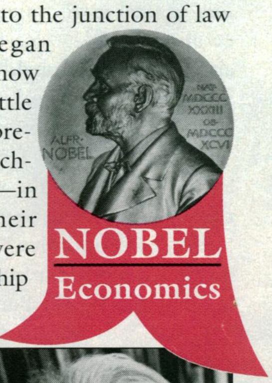
But the wonders of NMR have not stopped there. For the past 15 years, Ernst and others have developed three- and even four-dimensional techniques that are making NMR dear to the hearts of more and more non-chemists, notes NMR spectroscopist Ad Bax of the National Institutes of Health. Multidimensional NMR methods now complement x-ray crystallography as a means for determining structures of biological macromolecules such as proteins, he says.

And all of those things rest on the work done by Ernst. "All of the things that can be done with NMR are possible only because of the methods Ernst has pioneered and developed," says bioanalytical chemist Dallas Rabinstein of the University of California in Riverside, a heavy user of NMR spectroscopy. Indeed, Rabinstein and others agree that, even if Ernst was surprised when the airliner's captain gave him the news above the North Sea, others weren't. The prize had had his name on it for years. "Look for more [NMR-based] Nobel Prizes in the future," Ernst suggests. ■ **Ivan Amato**

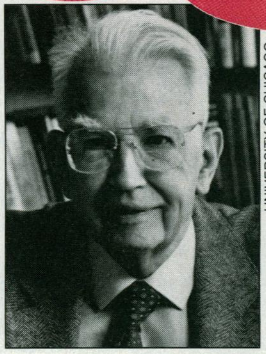
Economics: Transactional Analysis

Sometimes the deepest answers are elicited by the simplest questions. Why, for instance, are there nationwide chains such as Kinko's Copies instead of several thousand individuals ready to do your bidding with their own copiers and fax machines? Sure, economies of scale and the cost of capital equipment play a role. But for a fundamental explanation, you need to consider something called "transaction costs"—the expenses involved in drawing up and fulfilling agreements between producers and consumers. It's a lot quicker and probably cheaper to step into the local Kinko's, which offers a specific service for a standard, fixed fee, than it is to hunt down someone with a Xerox machine and negotiate terms. Considered theoretically, Kinko's is really nothing but an institutional framework designed to minimize the cost of such messy "transactions" by gathering them under one roof.

This insight into the nature of transactions has now won its originator, University of Chicago economist Ronald H. Coase, the 1991 Nobel Prize in economics. When Coase put forward the simple and easily accessible idea of transaction costs in 1937, he not only explained why businesses exist but also how legal restrictions affect human economic behavior—laying down, in the process, the foundation for a new discipline of law and economics. The Royal Swedish Academy of Sciences cites Coase's work as "among the most dynamic forces behind research in economic science and jurisprudence."



Coase's venture into the junction of law and economics began when he considered how individuals might settle disputes if nothing prevented them from reaching an agreement—in other words, if their transaction costs were zero. Prior scholarship held that such disputes—concerning, say, a farmer whose corn crop is regularly devastated by a rancher's herd—could be mediated only through government action, such as a law requiring the rancher to reimburse the farmer for crop damage.


UNIVERSITY OF CHICAGO

Ronald H. Coase

Coase, however, determined that the farmer and the rancher could reach an economically optimal settlement regardless of the legal environment. Suppose the cattle regularly ate $1000 worth of corn, while erecting a fence on the rancher's land would cost only $100. If the government forced the rancher to assume liability, the rancher would build the fence. But even in the absence of government action, the fence would still get built, although the farmer would have to pay the rancher between $100 and $1000 to do so. In either case, both parties would be better off than if no fence had been built.

In the real world, of course, the rancher could set an unreasonable price because he bears a grudge against the farmer. Or, if erecting a fence were to cost more than the damage to the farmer's corn, the farmer might scheme to collect damages by deliberately planting corn near the property line. Such non-zero transaction costs significantly complicate dispute resolution. As a result, Coase concluded that policy-makers should act cautiously when forging legal rules that might increase transaction costs. This "Coase theorem" is now widely taught in law schools across the United States, and has played a significant role in the development of the discipline of law and economics. Coase's ideas had "a direct, immediate effect on...lawyers, who began thinking about legal rules from an economic perspective," says Harvard professor of law and economics Stephen Shavell.

Outside of academic circles, Coase's influence is more difficult to assess. Political conservatives have used his theorem to argue against government interference in the economy, and at least two federal judges appointed by Ronald Reagan have been influenced by Coase's work. But conservatives are not alone in recognizing its value. "Regardless of how far you think the Coase theorem should take you in public policy, there's no denying that it's a seminal contribution to economics," says Lawrence Summers, a liberal Harvard economist now on leave at the World Bank.

Coase was vacationing in Tunisia last week, and wasn't reached with news of his Nobel for nearly 24 hours. The 80-year-old economist, described by a colleague as a man of "exceptional brevity and penetration," was characteristically brusque in his reaction. "What should one say about such an occasion?" he was quoted as saying in a university press release. "I'm interested only in promoting research." As if to prove it, Coase said he would use the nearly $1-million award to further economic research. "At my age, I'm not going to spend it on myself."

■ DAVID P. HAMILTON

Collagen: A New Probe Into Prehistoric Diet

Geochemists find that collagen may retain the memory of meals eaten thousands of years ago

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Neandertal. *A meat eater.*

Paris—STARTING WITH just a couple of chips of bone from the fossilized skull of a Neandertal, André Mariotti, a geochemist at the Marie Curie University in Paris, confidently announced last month that this early relative of man ate little other than meat. The reason for his confidence: a developing area of geochemistry that adds new meaning to the adage "you are what you eat."

Mariotti analyzed carbon and nitrogen isotopes in collagen extracted from 40,000-year-old Neandertal remains to determine the source of food that provided this protein's building blocks. The technique comes from ecology, where it has been used to establish the position of animals on the food web; Mariotti and his colleagues are the first to show that collagen isotope analysis can yield reliable data about ancient diets from fossils that are several tens of thousands of years old. Their results indicate that Neandertal man's dietary habits lay somewhere between those of the wolf and the fox—the wolf eats almost entirely meat but the fox gets some of its protein from occasional meals of fruits, grain, and even tree leaves.

"Its a very exciting result," says Henry Schwarcz, a geologist at McMaster University in Hamilton, Ontario, who is one of the small band of people using geochemical techniques to study ancient diets. Schwarcz has analyzed 10,000-year-old human fossils from France with the aim of seeing if people then were eating fish. Nothing as old as a Neandertal had been tested reliably, he says.

The key measures for paleodietary studies are the nitrogen-15 and carbon-13 levels in animal organic remains—usually in bone collagen, which can survive long after everything else has turned to dust. N^{15} gives clues to the position of an animal in the food web: There is more N^{15} in carnivores than in herbivores, and more still in carnivores that eat carnivores. Ecologists have worked out empirical rules for this isotope enrichment but do not fully understand how it arises. At least part of the explanation, however, is that N^{14} is excreted preferentially in urea, leaving a higher level of N^{15} behind in the body; animals that eat other animals will get a double dose of this enrichment.

C^{13} ratios directly reflect corresponding isotope ratios in plants at the base of the food web and give a host of clues about the types of plants in the diet. The environment (marine or terrestrial) in which the plant grows and the type of photosynthetic pathway—C_3, C_4, or CAM—all affect isotope ratios.

Putting N^{15} and C^{13} together it is often possible not only to distinguish between herbivores and carnivores but to tell whether a carnivore ate fish or meat or whether, in a savanna environment, a herbivore was a browser (eating C_3 shrubs) or a grazer (eating C_4 grasses).

The chief difficulty faced by Mariotti and his colleague, Herve Bocherens, in trying to push the use of these techniques far back in time is that collagen, although more durable than most other animal remains, does break down—the older the specimen, the harder it gets to extract sufficient quantities and the harder it is to be certain that the key isotope levels have not changed. To tackle the Neandertal, Mariotti teamed up with Jacques Paul Borel and Georges Bellon, two physicians from the University of Rheims who specialize in collagen diseases. Together, they were able to refine a method of identifying collagen by its amino acid spectrum, and then succeeded in extracting the protein from some 400 bone samples of fossils of reindeer, auroch, horse, marmot, hyena, wolf, and fox—as well as Neandertal—found at Maurillac, a famous cave site north of Bordeaux.

First results were encouraging: although the amounts of collagen extracted were often only about 2% of those found in modern