separate it from the rest of the plant, a task that itself may require capital-intensive extraction equipment. "Biotech is a very sexy area," says DuPont's Miller. "[But] there's a huge amount of science to be done."

By far the trickiest problem facing the new life sciences giants involves widespread public fears of genetically engineered products. Whereas such fears are only moderate in the United States, they resonate elsewhere, particularly in Europe, where much of the public remains skeptical of the safety of genetically modified organisms, particularly agricultural crops (*Science*, 7 August, p. 768). A Europe-wide poll published last year found that 53% of those surveyed said that current regulations are insufficient to protect people from the risks of biotechnology.

This public opposition is registering with politicians. Last week, the European Parliament's environment committee called on the European Commission to impose a moratorium on approvals to market genetically modified organisms. In July, the French government announced a temporary ban on commercial growing of genetically modified crops, and there has also been talk of a moratorium in the United Kingdom.

The atmosphere has grown so tense that last month a U.K. printer pulped the entire run of the September/October issue of the campaigning *Ecologist* magazine—a special issue focusing on Monsanto—reportedly fearing a libel suit by the company. (The issue has since been reprinted elsewhere.) Environmental organizations also continue to raise concerns that modified crops could cause unforeseen turmoil, such as invading new territory, passing on key genes to weeds, and contributing to the degradation of valuable ecosystems such as salt marshes by allowing farmers to grow salt-resistant crops and therefore plow up the land.

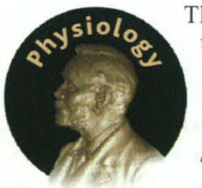
Gary Jacob of Monsanto says that "the fate of this technology has to be made by society in general." But such concerns raise questions about the wisdom of the chemical companies' bet on the life sciences. "They increase the risk," says Montague. Faced with these risks, DuPont, unlike Hoechst, Monsanto, and others, has decided to retain some of its chemicals business. "It's a matter of hedging our bets," says Miller. "We need a strong and healthy chemicals and materials business. But at the same time we're going to develop our capability in the biological sciences." But Montague argues that at this critical time, some boldness is necessary: "Unless you begin on the road, you'll never get anywhere."

—ROBERT F. SERVICE

NOBEL PRIZES

Nine Scientists Get the Call to Stockholm

The work honored by this year's crop of Nobel Prizes was done years ago but shows no sign of dating. The physiology prize went for the identification of a signaling molecule whose roles are still being explored; the chemistry prize for work enabling chemists to exploit quantum mechanics; the physics prize for a still-mysterious quantum "fluid"; and the economics prize for studies of poverty that remain all too relevant.



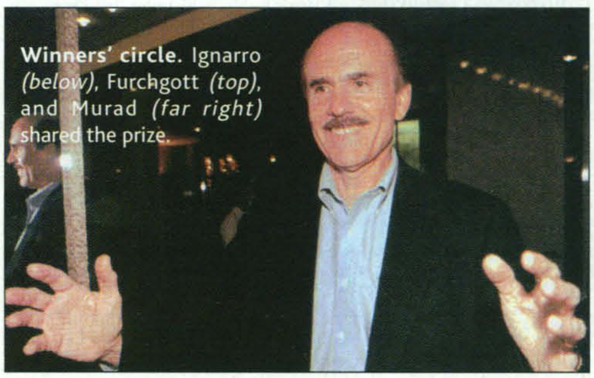
NO News Is Good News—But Only for Three Americans

The surprising discovery that the simple gas nitric oxide (NO) is a powerful messenger molecule in the body—a find that *Science* honored six years ago as "Molecule of the Year" and that helped spawn the impotence drug Viagra—has earned three U.S. researchers this year's physiology or medicine prize. The $975,000 prize was divided equally among pharmacologists Robert Furchgott at the State University of New York, New York City, Louis Ignarro at the the University of California, Los Angeles, and Ferid Murad at the University of Texas Medical School in Houston for identifying the first known gaseous signaling molecule and triggering a surge of further work on NO's diverse roles in the body. But the Nobel committee's omission of a fourth researcher, pharmacologist Salvador Moncada of University College London, drew fire from several senior scientists, including Furchgott himself.

"I'm delighted for the nitric oxide field, which Furchgott created, but I'm very disappointed Moncada has not been included," says pharmacologist John Vane of the William Harvey Research Centre at the University of London, a 1982 Nobelist for work on prostaglandins. Strict rules allow the Nobel committee to divide a prize between no more than three researchers. But Vane (who once worked with Moncada) and others say that this was the year for an exception, because Moncada carried out some of the key work showing that NO is released by cells.

Many researchers agree that Furchgott founded the nitric oxide field in the 1980s by recognizing that a mysterious signaling factor was at work in blood vessels. He wondered why drugs acting on blood vessels often gave contradictory and confusing results, sometimes causing a contraction and sometimes a dilation. He went on to show that the endothelial cells lining the inside of the vessels must be intact in order to receive a signal from compounds such as acetylcholine, which causes vessels to dilate. He concluded that the endothelial cells produce some unknown factor that relaxes smooth muscle and causes dilation. He called this factor endothelium-derived relaxing factor (EDRF).

Then, in 1986 Furchgott and Ignarro independently reported at a conference that EDRF is NO. The finding startled scientists because it showed that a simple gas—one best known at the time as a component of smog—can carry important informa-



Winners' circle. Ignarro *(below)*, Furchgott *(top)*, and Murad *(far right)* shared the prize.

CREDITS: (CLOCKWISE FROM TOP) A. NADEL; P. SULLIVAN; F. CASTANO/AP tion in the body, and it triggered a flurry of research worldwide. Over the last decade, researchers have confirmed that NO signals blood vessels to relax, which lowers blood pressure. Murad, working independently, discovered that nitroglycerin, a longstanding treatment for heart disease, works by releasing NO.

Other researchers showed that the gas triggers erection of the penis by relaxing smooth muscle cells and allowing blood to engorge the organ—a signaling effect enhanced by the drug Viagra. The gas also turns out to play both beneficial and harmful roles in the immune system: It may defend against tumors and infection by killing bacteria and parasites and inducing programmed cell death, but it can also trigger inflammatory diseases when overproduced in lungs and intestines.

Some researchers say Moncada deserves as much credit for this explosion of research as the Nobelists. Moncada's paper in *Nature* on the function of NO appeared in 1987, 6 months before Ignarro's own paper in the *Proceedings of the National Academy of Sciences*. The 1996 Albert Lasker Basic Medical Research Award—often seen as a harbinger of a Nobel Prize—stirred protests when it left Moncada out while honoring Furchgott and Murad for their NO work. The Nobel committee, which declined to comment on its decision, has now inflamed the controversy.

"Many of the fundamental discoveries have been made by Moncada, and he thoroughly deserved the award. The committee have made a mistake," says Max Perutz, winner of the 1962 Nobel Prize for structural studies of globin proteins. He and Vane had already complained to the Lasker committee about its failure to include Moncada in its 1996 award. Several other prominent scientists contacted by *Science* echoed these feelings. NO researcher Rudi Busse of the University of Frankfurt in Germany said he was "exceedingly surprised" that Moncada was not included.

Because Moncada is originally from Honduras, his exclusion has particularly angered Spanish researchers. The Spanish Cardiac Society, at its meeting this week, plans to consider a protest to the Nobel committee. Pharmacologist Pedro Sanchez Garcia at the Autonomous University of Madrid welcomed Furchgott's recognition but says he is "very sad" about the decision not to include Moncada.

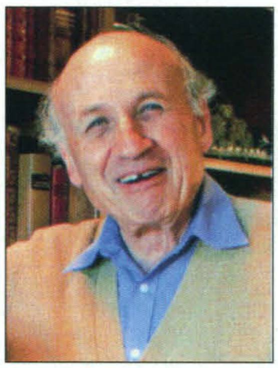
Moncada himself told *Science* that he was surprised by the Nobel committee's decision. "One wonders what criteria they use," he says. Furchgott, although delighted to win, said that he wished the Nobel committee had been able for one year to change the rules and include four people. "I think very highly of the work of the other winners, but I'm unhappy Salvador is not included."

–NIGEL WILLIAMS

Quantum Chemistry for the Masses

To chemists, quantum mechanics was once the scientific equivalent of a Hope diamond—beautiful and priceless, but essentially out of reach. This mathematical framework for understanding the behavior of atoms and their electrons—and hence of the chemical bonds they form—in principle opens the way to a complete understanding of chemical reactions. But as Paul Dirac, one of the theory's founders, put it in 1929, "the difficulty lies only in the fact that application of these laws leads to equations that are too complex to be solved."

The Nobel Prize in chemistry this year goes to physicist Walter Kohn at the University of California, Santa Barbara, and to mathematician and chemist John A. Pople of Northwestern University in Evanston, Illinois, for helping bring the diamond within reach. "Doing computational quantum chemistry is no longer a pipe dream," says Henry (Fritz) Schaefer, a longtime quantum chemist at the University of Georgia, Athens. Over the past few decades, Kohn and Pople independently developed theoretical shortcuts and computational methods that have created a foundation for the burgeoning field of quantum chemistry, enabling chemists to tap the vast theoretical power of quantum mechanics to understand, and even predict, the behavior of atoms, molecules, and the materials made of them.



Taming an intractable theory. Nobelists Pople *(above)* and Kohn.

CREDITS: (TOP TO BOTTOM) B. COOMER; R. MALDONADO/AP

Beginning in the mid-1960s, Kohn, a Vienna-born physicist who escaped as a teenager to England when the Nazis were overtaking Austria, began unlocking quantum mechanics for chemists by providing an alternative to the theory's central equation—Schrödinger's equation. The famous equation's so-called wave function describes the behavior of electrons around atomic nuclei, and it's relatively easy to solve for very simple bits of matter like a hydrogen atom, with its one proton and one electron. Even for small molecules with only 10 or 20 atoms, though, solving Schrödinger's equation can become computationally impractical. And biological molecules are in another realm altogether. "Imagine many … biological molecules or organic molecules with maybe hundreds of thousands of atoms with millions of electrons," Kohn said at a press conference last Tuesday. "In the Schrödinger picture," he continued, "we have a function that depends on millions of electrons."

Kohn's Nobel-caliber discovery was that a computationally much simpler accounting and mapping of the spatial distribution, or density, of the system's electrons can take the place of the mathematically intractable wave function. From the density map, chemists can go on to infer the stability, shape, and reactivity of the system. "It is astonishing that such a simple quantity like density can take the place of a wave function, which might be a function of a million variables," says Kohn.

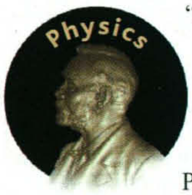
Observers say that at least half of all research papers incorporating computational chemistry now use density functional theory—and many apply it using computational tools designed by Kohn's fellow Nobelist, Pople. "Pople has been the master builder, who has made it possible for chemists to use quantum chemical methods as day-to-day laboratory tools along with their experimental equipment," said the Royal Swedish Academy of Sciences in the announcement of the prize.

Pople, who heard about the award while breakfasting with his wife at a Houston hotel, developed a range of mathematical tools and computational methods that opened up quantum chemistry for the broad mass of scientists. For example, he developed and validated an ever-improving and expanding library of "basis functions," which describe an electron's different energy components—such as its kinetic energy, nuclear attraction energy, and electron-electron repulsion energy—in specific molecular settings.

He incorporated these and other quantum-chemical tools into his GAUSSIAN computer program in 1970. Its successors have become as standard a tool for chemists as hammers are for carpenters. Users can, for example, stipulate a particular set of atoms and have the programs calculate the most stable molecular structure and geometry they can assume. The programs can also trace out detailed reaction mechanisms that would be extremely hard or impossible to discern experimentally.

With powerful and easy-to-use tools like these, quantum chemistry has infiltrated every nook and cranny of the chemistry community and beyond: "Atmospheric scientists, astrophysicists, geologists, and even neurologists are using it," says Mark Ratner, a colleague of Pople's at Northwestern. Chemists in search of new fuels for aerospace, for example, rely on quantum-chemical methods to screen candidate molecular structures for their energy content and stability, while astrophysicists trying to make sense of the radio emissions from interstellar matter use the methods to simulate the radio spectrum of candidate molecules. From being an unattainable diamond, says Ratner, "quantum chemistry has become a black-box procedure that anyone can use." —IVAN AMATO

Ivan Amato is a correspondent for National Public Radio and the author of *Stuff*, a book about advances in materials science.



A Prize for Quantum Trompe l'Oeil

"An electron is an electron is an electron," Horst Störmer says cheerfully, a day after he and two colleagues won the 1998 Nobel Prize in physics for work that seemed to show just the opposite. Störmer—at Columbia University in New York and Lucent Technologies' Bell Laboratories in New Jersey—shared the prize with Daniel Tsui of Princeton University and Robert Laughlin of Stanford University for discovering a seeming exception to the textbook rule that every electron has the same electric charge. Sandwiched in a semiconductor at close to absolute zero and saturated in a powerful magnetic field, they found, electrons can perform an elaborate dance in which they act as if they had just fractions of that indivisible charge.

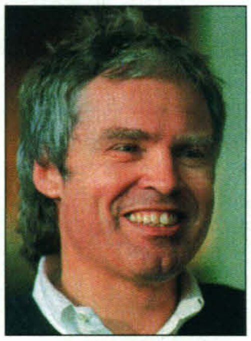
Called the fractional quantum Hall effect, this dance of fractional charges reflects the properties not of single electrons but of a "quantum fluid" melded from the electrons and the lines of magnetic force. "It's so totally unlike states of matter that we had previously encountered," says Princeton's Philip Anderson, who won a physics Nobel in 1977. The finding is so suggestive that its implications could reach outside semiconductors to the swirling, evanescent particles of "empty" space itself.

The fractional quantum Hall effect is the high-tech grandchild of an effect observed in 1879 by Edwin Hall. He applied a magnetic field at right angles to a current-carrying gold plate and found that a voltage drop developed across the plate. Rather than flowing straight down the plate, the electrons tried to orbit the magnetic field lines, causing electrons to pile up on one side and produce the voltage drop.

The voltage drop across the plate, simply called the Hall effect, is directly proportional to the strength of the magnetic field. But in 1980 a German physicist, Klaus von Klitzing, tried the same experiment at low temperatures and high magnetic fields in high-quality silicon—a semiconductor in which electrons can be induced to move only along a two-dimensional (2D) surface. Under those conditions, the electrons could execute their magnetic orbits almost undisturbed by collisions with imperfections or thermal vibrations in the material. This freedom allowed a new effect to emerge: The voltage drop changed in steps, rather than smoothly, as the field was cranked up.

The steps, von Klitzing realized, showed that the electrons in the 2D layer had become quantized. Like electrons in an atom, they could only swirl around in orbits at particular energies, determined by the equations of quantum mechanics. The lowest of these energies, called the ground state, is the one a cold electron naturally falls into. But if the ground states are all occupied, the electron goes into the first available excited state, corresponding to a larger orbit.

The stronger the magnetic field von Klitzing applied, the tighter all of those orbits became and the more of them could fit across the face of the silicon sample. At relatively weak fields, ground state orbits were scarce, and the electrons piled up in the excited states. At higher fields, however, more electrons could settle into the ground state, lowering the "filling factor"—the ratio of electrons in excited states to electrons in the ground state. Each time the filling factor dropped by one, meaning that another excited state had emptied, the Hall voltage suddenly shifted. "As you hop from one quantum level to the next one, you see the steps," says Störmer. This quantum Hall effect won von Klitzing a Nobel Prize in 1985—and it had the strange offspring being celebrated this year.



Electron splitters. Physics Nobelists Tsui *(top)*, Störmer, and Laughlin *(bottom)*.

In 1982, Störmer and Tsui were studying electronic effects in a new gallium arsenide–based semiconductor made by Arthur Gossard, now at the University of California, Santa Barbara. The new device allowed the electrons even more freedom than they had in von Klitzing's silicon-based one. When the researchers boosted the field strength to levels above those that von Klitzing had explored, they saw further steps. The first new step popped up at a filling factor of one-third—just what would happen if particles with a third of the electron's charge were lurking in the sample.

"We've discovered quarks," Tsui quipped at the time, referring to elementary particles with a one-third charge that can be detected only in particle accelerators. Laughlin, a theorist, later worked out what was really going on. The electrons' high mobility in the new semiconductor had freed them to interact in new ways, producing "quasi-particles": collective effects that mimicked the pipsqueak particles.

The quasi-particles are quirky cousins of an effect that occurs when a charged particle zips through an ordinary semiconductor or an ionized gas: Particles of the opposite charge (or "holes," where same-charge particles are absent) cloud around it and shield it from the outside world. In the cold, magnetized quantum sea of electrons in gallium arsenide, the shielding happens most easily when three vortices, each with a positive one-third charge, cluster around an electron, although the vortices and electrons can also congregate in other ratios. Sometimes those vortices float freely, and they are the quasi-particles.

The phenomenon shows, says Laughlin, "what the laws of quantum mechanics can do that you would never in your wildest dreams have thought of." And Tsui's quark quip might turn out to have more substance than it seems, says Laughlin: As real as ordinary quarks appear to be, they could conceivably be the manifestation of a related quantum-mechanical trompe l'oeil, conjured up by the evanescent particles in the continuum of free space. But most physicists are still mulling over the strangeness of the Nobel-winning fluid.

CREDITS: (TOP TO BOTTOM) C. R. ARBOGAST; M. DERER; S. RAGAN/AP

Says Steven Kivelson of the University of California, Los Angeles: "It's really deep, and it's really quantum mechanical."

–JAMES GLANZ

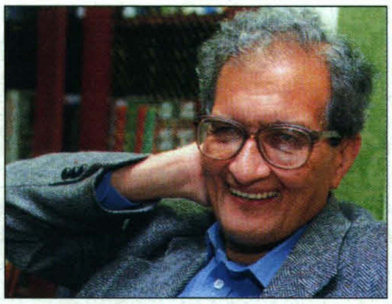
Economics

Famine Survivor Wins Economics Prize

In 1943, despite a robust economy and an ample harvest, a famine engulfed the Indian state of Bengal and killed up to 3 million people. Last week, a child survivor of that disaster who went on to develop an economic explanation of how starvation could occur amid plenty won the Nobel Prize in economic sciences. In awarding the prize, the Royal Swedish Academy of Sciences cited 64-year-old Amartya Sen for his contributions to the field of welfare economics and for restoring "an ethical dimension to the discussion of vital economic problems."

Sen, who earned a doctorate from Cambridge University in 1959 and recently returned to its Trinity College to teach, has spent the past 3 decades on problems ranging from how government spending choices influence individuals to how researchers should best calculate poverty statistics. But he is perhaps best known for work that offered a fresh look at the economics of famine. Studies of disasters in India, Bangladesh, Ethiopia, and Saharan Africa led Sen in the 1970s to challenge the conventional view that famines are caused solely by food shortages. Instead, he showed that other factors—such as declining wages and rising food prices caused by bad weather or flawed government policies—influence the distribution of food and aggravate famine conditions for the poorest people. "Many past famines have been associated with high inflation, making the groups that fall behind in the inflationary race selected victims of starvation," he wrote in a 1996 paper for the journal *Development*.

"[Sen] achieved something very rare in economics," says a former student, economist Prasanta Pattanaik of the University of California, Riverside, who praised Sen's ability both to develop highly abstract theory and apply it to real world problems. In studying poverty, for example, Sen helped devise measures that do more than just show how many people fall below a nation's poverty line. The new indices, now in wide use, show how far below the line people fall and also identify social factors—such as poor health and limited education—that reduce economic mobility. The approach, described in dozens of books and papers, has provided policy-makers with useful information for devising solutions, including the knowledge that policies designed to help individuals just a few dollars below the line may do little for those deeper in poverty.



A caring science. Sen has added an "ethical dimension" to economic analysis.

Sen has "pushed people to think about poverty in much broader dimensions" and influenced international development policies, says economist Lyn Squire of the World Bank in Washington, D.C. In particular, he says, "the development community has moved away from looking at poverty with a narrow focus on income and [toward] ways to empower the poor to make choices."

The ethical implications of economic policy have long concerned Sen, who until recently held chairs in both economics and philosophy at Harvard University. "Economic analysis," he argued in a 1990 speech to Italy's Agnelli Foundation, "has something to contribute to substantive ethics in the world in which we live."

–DAVID MALAKOFF

NEUROSCIENCE

Researchers Go Natural in Visual Studies

Artificial stimuli are usually used to probe visual processing, but recent work with natural images is providing some surprising new insights

When you look out your living room window, chances are you will see a scene that's a lot more complex than bars of light or fields of moving dots. But those are the kinds of visual stimuli neuroscientists have used for decades to understand how the brain interprets the visual world. "The idea is that what you learn from these simple stimuli is going to generalize and tell you how [the visual system] would respond to a real scene," says neuroscientist Bruno Olshausen of the University of California (UC), Davis. "But that is just an assumption ... that has never been tested"—until now, that is.

Within the past decade, a small cadre of neuroscientists has begun to determine how the visual system responds to "natural scenes," defined as images from the real world, whether they depict jungle foliage or a city street. The work is providing new insights into why visual neurons have evolved the properties they have, what controls the responses of individual neurons, and how our brains process the images we actually see. It turns out, for example, that when the visual system responds to complex natural scenes, interactions between neurons are much more important than had been previously known. Researchers also hope that natural scenes will help them understand the functions of some visual neurons whose activities until now have been a complete mystery.

Here's looking at you. Cats' visual neurons fire more efficiently when they look at movies like *Casablanca* than when exposed to visual "white noise" (*inset*).

Among the first neuroscientists to experiment with natural scenes were computer modelers, in part because it is easier to analyze a model's response to a complex scene than that of a real brain. In one striking example, Robert Barlow and his colleagues at the State University of New York Health Sciences Center in Syracuse used a computer model to ask how a horseshoe crab's eye responds to a

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