turns out to be the cleanest possible way to probe for hard, point-like structures in the proton. If such structures exist at all, he pointed out, they would make their presence known by deflecting some of the inelastically scattered electrons through a very wide angle. Their signature would be unmistakable.

And that, to the astonishment of everyone, was exactly what the SLAC-MIT team found. In effect, each wide-angle electron they saw was resolving Hofstadter's fuzzball into a mass of hard little granules. Indeed, by the time Taylor, Friedman, and Kendall had completed checking and cross-checking their experiments in the early 1970s, they had not only demonstrated that the granules inside the proton were in fact the long-sought quarks, but they had also demonstrated that the quarks themselves were embedded in a sea of electrically neutral "gluons" that held them together.

"It was a milestone in our understanding of matter," says Panofsky. At a stroke, the SLAC-MIT experiment ended decades of confusion and ambiguity about the fundamental structure of the particles and laid the groundwork for the unified theories of the strong, weak, and electromagnetic interactions that followed almost immediately.

And, Panofsky adds, the result was a testament to the three researchers themselves. "They didn't set out to look for point-like structures in the proton," he says. "It was a surprise—that they creatively took advantage of. They were experimentalists' experimentalists." ■ **M. MITCHELL WALDROP**

Three "Practical" Economists Share Nobel

The 1990 Nobel Prize in Economic Sciences was awarded last week to three Americans whose work explains how individuals and corporations make investment decisions. They are Harry Markowitz of the City University of New York, Merton Miller of the University of Chicago, and William Sharpe of Stanford University. Widely known not only to academics but to the professional economists on Wall Street, the three have done much to shape today's stock and bond markets. Mutual fund managers, for example, follow general principles for designing portfolios that were laid down by Markowitz and elaborated by Sharpe, and Miller's work guides many decisions on corporate financing.

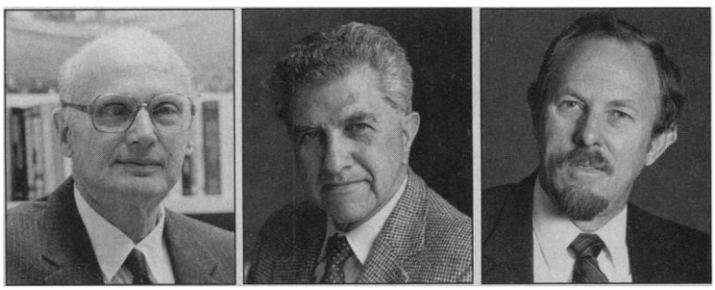
The prize signifies the acceptance of finance—which for many years was taught in business schools instead of economics departments—as an integral part of economic theory, says Franco Modigliani, a Massachusetts Institute of Technology economist and 1985 Nobel laureate. The three prizewinners were part of a group of researchers in the 1950s and 1960s who put finance on a rigorous theoretical footing. And, Modigliani adds, "This rigorous approach has really spun off many practical applications."

Modern portfolio design, for instance, can be traced back directly to Markowitz's work in the 1950s. In his theory of portfolio selection, developed in his 1955 Ph.D. dissertation at the University of Chicago, Markowitz worked out simple formulas to determine the best way to choose investments so that risks are minimized while potential rewards are maximized. A key insight of this work was the realization that the total risk of a portfolio of stocks and other assets depends not just on the risks of the individual investments but on the correlations between those risks. The risk of investing in an auto maker, for instance, can be somewhat balanced out by buying stock in an oil company, since a sharp rise in the price of oil may hurt the auto company's profits but should increase those of the oil corporation. Markowitz developed a mathematical model for evaluating the aggregate risk of a portfolio of investments.

Sharpe applied Markowitz's work to understand how markets such as the New York Stock Exchange determine the prices of securities. "For quite a while, economists thought that the stock market was a casino," Modigliani said, "so there was little interest in it." But Sharpe, along with several other economists in the mid-1960s, showed how an efficient market bases the prices of securities on their potential risks and their expected returns—an observation that seems obvious now but was not at the time.

In a surprising spin-off of this work, Sharpe showed that a speculative investment strategy and a cautious one should differ only with regard to how much each puts into risky investments, not what the risky investments are. A cautious investor might buy mainly government bonds with only a small percentage of his money going into the stock market, while a speculator might even go into debt to play the market. But the money each of them puts into the stock market is best invested in the same way: In the absence of special knowledge about how certain stocks will perform, the most efficient way to take risks is to put money in a highly diversified portfolio that follows the market. This reasoning underlies the existence of today's "market funds."

In the late 1950s and early 1960s, Miller, initially in collaboration with Modigliani, investigated another practical economic question: Should companies finance expansion by issuing more stock or by borrowing the money? That had been a central issue in finance, but Miller showed that it didn't make any difference—that a firm's market value and average cost of capital remained the same no matter whether it chose equity financing or borrowing. "That caused enormous commotion at the time," said George Stigler, an economist and Nobel laureate at the University of Chicago. But Miller was able to substantiate his result by putting together a database that tracked stock prices from the New York Stock Exchange from 1926 on. Different tax treatments of borrowing and equity financing modify their impacts on a company, however, and Miller has extended his original analysis to determine how varying tax policies affect a firm's capital asset structure. John Gould, dean of Chicago's Graduate School of Business, says that Miller's findings have "changed the way finance is taught in the United States and around the world." ■ **ROBERT POOL**



Financial wizards. *Harry Markowitz, Merton Miller, and William Sharpe helped make financial economics a rigorous science.*

CUNY, University of Chicago, Stanford University