The visual image in the former group is already represented, in optic nerve, as an overlapping array of patches locally described in terms of moving boundaries and the directions of motion and, in general, with properties very similar to those of Hubel and Wiesel's cortical cells. But while these animals certainly have good binocular vision by behavioral test, it is not obvious that they enjoy stereoscopic vision in the sense that is stressed by Helmholtz and, later, so clearly developed by B. Julesz. The direct perception of the world as a three-dimensional image is very different from the apperception of its three-dimensionality by experience, instinct, or reason. I have no idea of how to put numbers to the matter, but it seems to me that processing two flat images to a single solid image, when the flat images are given in terms of boundaries, requires far too much operation, every patch seen in the light of all the others. The cyclopean eye (the stereo view of a single world) that Helmholtz and Julesz treat, is one in which the processing itself, patch by patch over the visual field, determines depth as well as extension along the image plane before the form is construed, even before edges are definitively taken. And this requires, I think, that as Kuffler found, the ganglion cells of animals blessed with stereoscopy take a kind of textural context around a central region of the receptive field rather than any more explicit operation on continuous boundaries. It also requires that the cortical operation can be done under conditions of disparity in the two representations offered (particularly along the interocular axis) so as to free the system from the impossible job of registering, point by point, two different views of the same scene. And all this must be done without loss of resolution.

That processing for depth occurs independently of clearly bounded form was proven by the ingenious experiments of Julesz. Accordingly, the objects of perception and the space in which they seem to lie are not abstracted by a rigid metric but a far looser one than any philosopher ever proposed or any psychologist dreamed. And precisely here the mammalian cortex, in the hands of Hubel and Wiesel, poses one of the most fascinating and complex problems in contemporary brain science. By their descriptions, the problem has assumed its proper status, that of a remarkably clever program of processing to which very specific kinds of image dissection are necessary. They have, thereby, opened a new field in the physiology of vision.

On the practical side, the treatment in pediatric ophthalmology is indebted to them. For in a collateral branch of their research, they did a tour de force of some consequence. As they showed, a newborn kitten has a visual cortex capable of handling the disparate images of the binocular animals. Between the third and fifth postnatal weeks there is a critical period in this sense: Let one eye be deprived of form, but not of light, as with a diffuser, or be caused to squint so that the image represented to the cortex is much displaced out of tolerable disparity. Then the central connections of that eye change functionally, and the ill-seeing eye is suppressed from the cortical processing. Its nerve fibers still report to the geniculate body, and the geniculate still reports to cortex, but the reports are mainly discounted. And this functional blindness persists thereafter even though normal imaging and registration in that eye is restored.

This study gives the lie to the notion that children born with a squint can grow out of it several years later and have normal stereoscopic vision, or even normal equivalent use of the strabismic eye. The same experiment that showed for the first time in higher animals how experience changes connectivity of the brain, showed also the folly of not intervening as soon as possible before the critical period. For whenever that period occurs in children, and it occurs early by all indications, it so reconnects the system functionally that no cosmesis, however attained later, can rectify the trouble. Reflect that this same principle may hold true for many other systems, including the higher functions, that critical periods occur all through a child's growth, and be properly awed by the new view of pedagogy that emerges. On this one major step, were this the only thing they had done, Hubel and Wiesel eminently deserve the honor accorded them.

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1981 Nobel Prize in Economics

When Albert Einstein's first marriage broke up, he promised his wife as alimony the proceeds he would be getting from the Nobel Prize. So certain was he to get it that this was like money in the bank. The only wonder was that it was so late in coming, and that the Royal Swedish Academy of Sciences went out of its way to make clear that the award had not been given for Einstein's work in relativity. (In rebuke, Einstein devoted his Nobel Lecture to the subject of relativity.)

It was just as certain that James Tobin would receive the Nobel Prize in Economics. It was never a question of whether, only of when. The breadth of Tobin's work in empirical macroeconomics and the depth of his many analytical innovations make this a popular award in a field of not-so-hard science, where not all awards are greeted with unmixed enthusiasm.

I shall try to give a sample of Tobin's researches. But first it is worth examining the scholar as a person. For James Tobin is the archetype of a late 20th-century American scholar.

Son of the Middle Border

Tobin had to win the Nobel Prize because he can't help winning any prize that's out there. This began at nursery school in Champaign, Illinois, that oasis of culture and incubator for Nobel Laureates in diverse fields. Michael Tobin, his father, was publicity director for athletics at the University of Illinois, and his eruptions at the conservatism of Colonel McCormick's *Chicago Tribune* recruited Jim early into the camp of liberalism.

Prior to 1935 Harvard College was still a finishing school for Grottlesex gradu-

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ates and commuting Bostonians. President Eliot's creation of a university had been followed by President Lowell's nurturing of a college. The new President Conant was engaged in the alchemy of converting Harvard into a meritocracy. James Tobin, fresh from University High and quite ignorant of the Porcellian and other final clubs, was one of the first of the meritocrats, entering with the class of '39 as one of the new National Scholars. Sandwiched between John F. Kennedy's class of '40 and Joseph Kennedy, Jr.'s class of '38, the end of the decade's class is worth contrasting with the beginning of the decade's. The class of '31, which contained both Douglas Dillon, the future financier, and Paul Sweezy, the future interpreter of Marx, included more millionaires than socialists. The class of '39, with Alan Lerner, Leonard Bernstein, and James Tobin, foreshadowed the new Harvard that was being formed.

Wide World Photo

James Tobin

One must be born at the right time. For a future quantum physicist, 1897 was a good birth year. Lucky Jim was a freshman when John Maynard Keynes's revolutionary *General Theory of Employment, Interest and Money* burst upon the economic world (*1*). Never having acquired immunity from orthodox antibodies, Tobin was a pushover for the new heresies. His teachers were nine to two against Keynes; but one of the two was Alvin Hansen (*2*), and the issue was never in doubt.

After a tour of duty in the prewar Washington agencies preparing for military mobilization, Tobin joined the Navy, picking up the customary gold watch for best officer in his training class. His sea duty is recorded in *The Caine Mutiny*, written by his classmate Herman Wouk (*3*). Tobin is the high-foreheaded, silent mandarin portrayed there. In a profession not noted for its taciturnity, Tobin is indeed a silent person, who passes on to those he has newly met not every clever thing he knows.

Returning to Harvard at war's end, Tobin was elected into the Valhalla of the Society of Fellows. Promising Junior Fellows often become tenured Harvard professors. But when Yale called, James Tobin acted in the way economics pretends everyone acts: he took the best offer held out to him.

The old Yale economics department was notoriously conservative. It tells us something about William Buckley's sophistication as a youngster that in his *God and Man at Yale*, he regarded that assembly of scholars as a hotbed of subversion (*4*). So rapid is the metabolism of a university, that in half a decade Lloyd Reynolds and James Tobin built up a team that put the Yale economics department in the first few of American departments. I once quipped to Alvin Hansen, "Yale is the best Harvard department outside of Cambridge." His sober reply was, "Harvard should be so good."

Important for Yale and the development of econometrics was the decision of the Cowles Foundation to transfer its research unit from the University of Chicago. Everyone was happy: Chicago could document undisturbed the efficiencies of the marketplace; Yale could recruit Jacob Marschak, Gerard Debreu, and Tjalling Koopmans (Nobel Laureate, 1975) while hanging on to James Tobin; the science of econometrics could enter a golden age.

All biography loses interest after success comes. Suffice it to say that James Tobin lived happily ever after in New Haven, and during The Game can be heard to boo Harvard like any apoplectic old blue from Bones.

Portfolio Theory

I must be selective in sampling Tobin's scientific contributions. Here is one, important for itself, and vital as a precursor to the exciting development of modern portfolio theory.

Keynes, faced with the Great Depression, had to explain why people held so much idle cash relative to their annual dollar incomes. Irving Fisher, Yale's reformer zealot and America's greatest economist of the pre-1930 era, believed that the velocity of circulation of money, V, was a fundamental constant (rather like the speed of light). To understand the depression drop in V, Keynes devised a theory of "liquidity preference" along the following lines:

> Although you can buy long-term bonds that pay an annual coupon yield, you will still keep some of your wealth in the form of zero-interest cash because you fear that interest rates will soon rise back to their prosperous-times level, thereby causing bond prices to fall by even more than the bonds' interest returns.

This is perhaps not a bad theory for the years in the 1930's when memories of pre-1929 were very fresh. But young Tobin came up with a better theory to fit the 1950 facts, which were that investors could rationally expect that bond prices might go up *or go down* depending on the uncertainties of future interest rates.

Tobin knew the mathematical probability theory of Pascal, Fermat, Laplace, and Kolmogorov (*5*). He recognized that the expected ("mean") value of a risky security's total return—its interest coupon or cash dividend, corrected by its percentage change in market price—can typically be taken to exceed the zero-return of cash (or the minuscule yield on absolutely safe cash equivalents).

But Tobin also knew the St. Petersburg paradox and the work of Daniel Bernoulli, Laplace, and Bentham which suggested that people are typically risk-averse (*6*). The thousand dollars we stand to gain in a fair-coin toss does not mean so much to us in utility terms as the thousand dollars we stand to lose. So Tobin, like economists and philosophers before him, assumed that what counts to

us in making our portfolio decisions is maximizing the expected value of the utility of money outcomes, not the mere expected value of money itself (*7*).

The moral: Risk-averse people who are subject to the law of diminishing utility will want to put part of their wealth in a risky security that promises a higher mean return than safe cash does. But they will not want to put all their wealth into the asset that could leave them very badly off. "Don't put all your eggs in one basket" is the philosophy they follow. Other things equal, a drop in the expected return on stocks and bonds, and their increased variabilities associated with depression, should make us expect that people will hold more cash in depression relative to total wealth and total income. The drop in money's velocity is explained once its V is made to be a rising function of the prevailing interest rate, $r : V = f(r), f'(r) > 0$.

James Tobin also measured econometrically the dependence of V on r (*8*), a result congenial to neoclassical pre-Keynesian orthodoxy and verified by all statistical investigators with the exception of some monistic Monetarists.

I have skipped in this account Tobin's ingenious approximation, by means of which a security's mean, μ, and its variance (or mean squared deviation), σ^2, are used as proxies for its whole probability distribution. This convenient approximation, which, independently of Tobin, Harry Markowitz was also exploring at the Cowles Commission (*9*), applies well under various conditions (*10*): (i) if my marginal utility schedule is nearly linear; (ii) if the probabilities I face are bunched (as they will be if I can instantly rebalance portfolios subject to a Wiener-Itô-Merton process of the type Einstein analyzed for Brownian motion) (*11*); or (iii) if the security is almost subject to a Gaussian probability distribution (for which μ and σ are sufficient parameters).

The mean-variance analysis was applied to portfolio choices among cash and many securities: Confronted with the mean returns per dollar of cash on each of n risky securities, and given the n^2 variances and covariances of the n securities' joint probability distribution, Markowitz and Tobin solve by a quadratic-programming algorithm for the set of "efficient" portfolio weightings that provide minimum total portfolio variance for each tolerated total portfolio mean. Investors with little risk tolerance will select an efficient (mean, variance) portfolio heavily weighted by cash, which sacrifices mean returns for safety; investors with more nearly constant marginal utility will hold less cash in their efficient portfolio and achieve higher mean returns at the cost of variability.

The theory accords with common sense. Despite the difficulty in getting estimates from past data of means and variances that are relevant for the future, the theory is useful in practice. In the hands of W. F. Sharpe and John Lintner, it has developed into the important capital-asset-pricing model, according to which markets will be efficiently priced already so that prudent investing calls for the broadest possible diversification into everything out there in the marketplace, and with very low turnover (*12*).

Post-Keynesian

When I described Tobin as an archetypical present-day scholar, I had in mind his concern for policy as well as for theory and empirical inference. He served, along with Walter Heller and Kermit Gordon, on the famous Camelot Council of Economic Advisers to President John F. Kennedy. A supply-side economist before Arthur Laffer had matriculated or David Stockman had been weaned, Tobin was one of the architects of the investment tax credit designed to promote capital formation and productivity. To his disappointment, politics thwarted Tobin's proposed consideration of austere overbalanced budgets and low-real-interest credit policies to shift our full-employment mix toward less consumption and more investment. (This is the opposite of what Wall Street believes the Reagan program will be.)

The Nobel Committee was less enchanted with Milton Friedman's monetarist theories than the lay press is, and was more admiring of his contributions to our understanding of a market system's workings and merits. They went out of their way to stress the latter contributions. (Friedman, like Einstein, gave the Stockholm lecture he chose to give.) Similarly, in 1981 the Swedish commentators have expressly ignored Tobin's role as one of the few prepared to debate the ideologies and findings of Monetarists—who go beyond the view that "Money does matter" to the view that, when it comes to macroeconomic inflation control, "Only money matters." Whatever the Royal Swedish Academy wishes to stress, James Tobin is known as a macroeconomist whose value judgments weight heavily the real costs in the short run of combating inflation. His optimal rules for conducting monetary and fiscal policies are not content with mere attempts to stabilize the growth rate of Money 1B, or Money 2, or of any one of the two dozen alternative definitions of the total money supply.

The Reagan team is unlikely to heed Tobin's counsel. But democracy can never afford to disregard the findings of scholars just because their value judgments are momentarily out of fashion.

What Price Prizes?

Alfred Nobel did not include economics in his will. From 1901 to 1969, there was no Nobel Prize in Economics, just as there still is no such prize in mathematics. When the Bank of Sweden decided to fund an economics prize to celebrate its own 300th anniversary, the committee set up by the Swedish Royal Academy of Sciences endeavored to lean over backward in eschewing layman's popularity and emphasizing the elements of science within political economy.

Making James Tobin the 19th laureate—the 10th American laureate—I feel adds to the luster of my own medal. It gives hope to each creative scholar anywhere in the world that she, or he, may also earn the esteem of scientific peers, which is indeed the coin that all researchers work for.

—PAUL A. SAMUELSON

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