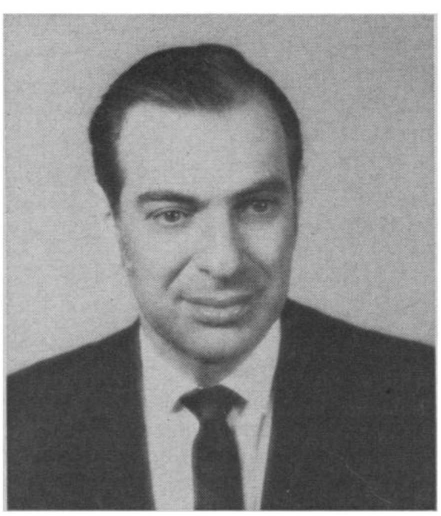
The 1972 Nobel Prize for Economic Science

In the fourth awarding of this new honor, the committee of the Swedish Royal Academy of Science continues to emphasize scholarly achievement within the discipline of political economy rather than more popular and direct influence on policy. Two distinguished theorists share the award: Sir John Hicks (born in 1904), emeritus Oxford professor [and earlier holder of academic posts at the London School of Economics (LSE) and at the Universities of Cambridge and of Manchester]; and Kenneth J. Arrow (born in 1921), now at Harvard but long the sparkplug of a brilliant group of economists at Stanford University.

Although the citation groups the two "for their contributions to general equilibrium," each has done quite different work in this common field. And, although the citation properly points out the difference in their ages, informed scholars are aware that Hicks continues to make contributions of the first rank, just as he has been doing for 40 years.

Arrow is one of the new breed who come to economics with good training in economics and statistics. Hicks, who read PPE (Politics, Philosophy, and Economics) at Oxford, is self-taught and necessarily more intuitive and heuristic (*1*).

Both men made their first breakthroughs just before the age of 30: In the case of Hicks (*2*), *The Theory of Wages* (1932) and (with R. G. D. Allen in 1934) research in demand theory that culminated in *Value and Capital* (1939); in the case of Arrow (*3*), his Impossibility Theorem for Ideal Democratic Resolution of Divergent Preferences (1949–1951), and in 1952 his revolutionary reformulation of the theory of risk by means of the concept of contingent securities. In this age when patronage of pure science by government and foundations is much discussed, it is worth noting that Arrow's social welfare theories first saw the light of day as Rand Corporation memos; the finished form *Social Values and Individual Choices* (1951) appeared as a Cowles Foundation monograph at the University of Chicago; his 1952 risk breakthrough was aided by an Office of Naval Research grant.



Kenneth J. Arrow

I can only sample typical researches by such prolific authors. I begin with Hicks.

Dynamics of the Distribution of Income

In the *Theory of Wages*, Hicks supposes real gross national product (GNP), Q, to be subject to neoclassical models of distribution:

$$Q = Q(V)$$
$$= Q(V_1, V_2, \ldots), \quad \text{a concave function}$$
$$= \lambda^{-1}Q(\lambda V), \quad \text{first-degree homogeneity}$$
$$= \sum_1^n V_j \partial Q(V)/\partial V_j, \quad \text{Euler's theorem}$$
$$w_i = \partial Q(V)/\partial V_i, \quad \text{marginal-product factor pricing}$$
$$\alpha_i = V_i \partial Q(V)/\partial V_i, \quad \text{relative factor shares in GNP}$$

Here, (w_j) are the real prices of the respective (V_j) factors; w_1 is the real wage of labor, V_1; w_2 is the rent of land, or (as Hicks tells us he now regrets as oversimplified) w_2 is the interest rate of some homogeneous aggregate of capital V_2.

For the most part Hicks worked with labor and capital only. He correctly perceived that capitalism has shown greater growth of capital than of labor. Without technical change, he verifies that the interest or profit rate would fall, and the real wage rise—this by virtue of

$$\partial^2 Q/\partial V_i^2 < 0 < \partial^2 Q/\partial V_i \partial V_j$$

What happens to property's relative share in GNP, $\alpha_2 = (V_2 \partial Q/\partial V_2)/Q$ as V_2/V_1 grows? Hicks shows that α_2 will fall, rise, or stay the same, depending upon whether his newly defined "elasticity of substitution,"

$$\sigma = (\partial Q/\partial V_1)(\partial Q/\partial V_2)/Q\partial^2 Q/\partial V_1 \partial V_2$$

is less than, greater than, or equal to unity. (Implicitly, Hicks seemed to believe $\sigma < 1$.)

Even more important is his analysis of how technical invention affects distribution. Put a technical change parameter, t, in $Q(V_1, V_2;t)$ with $\partial Q/\partial t > 0$. Then its effect on relative shares depends, Hicks shows, on whether invention is labor-saving or capital-saving; that is on whether

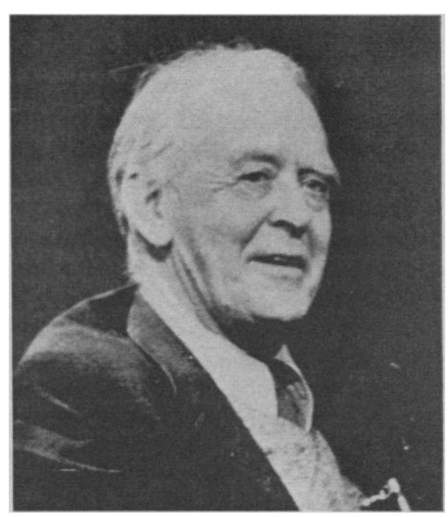
$$\partial/\partial t\{(\partial Q/\partial V_2)/(\partial Q/\partial V_1)\}$$

is greater than or less than zero.

Hicks develops the notion of Marx that, every time capital accumulation tends to raise labor's share, this induces labor-saving technological research and development—with the result that the relative share in GNP of wages has been remarkably constant (the so-called Bowley's Law).

Pure Theory of Demand

The analytical core of *Value and Capital* defies brief synopsis. Without having known of E. Slutsky's 1915 work in Italian, Hicks built consumer-demand theory on the behavioristic basis of "The Batch of goods A preferred to Batch of goods B," with no



John Hicks

attempt to say "There exists numerical utility, $U(X^A) = U(x_1^A, x_2^A, \ldots)$, which is greater than $U(X^B)$."

But now what happens to our commonsense notions: "Coffee and tea are *substitute* goods. Tea and lemon are *complementary* goods." The old test fails: "If the sum of increments of utility that I get from experiments that increase but one good at a time exceeds the increment of utility I get from increasing both goods *together*—then (like tea and lemon) they are complementary goods."

Hicks ingeniously proposed an alternative behavioristic test: "Raise the price of coffee and raise the consumer's income just enough to leave him as well off as before. If the amount bought of tea now goes up, tea and coffee are *substitutes*; if the amount of cream goes down, cream and coffee are *complements*." Then, just as Clerk Maxwell had proved reciprocity relations in thermodynamics (dependent on $\partial^2E/\partial V\partial S \equiv \partial^2E/\partial S\partial V$), Hicks proves that

$$(\partial x_i/\partial P_j)_U \equiv (\partial x_j/\partial P_i)_U$$

that is, if tea is a substitute for coffee, coffee must be a substitute for tea.

All this he applies to bonds and stocks as well as consumption goods, contributing to the revolutionary advances in business cycle control that we associate with Keynes's *General Theory of Money, Interest and Employment*.

Existence of General Equilibrium and Its Dynamic Stability

Before describing what I regard as Arrow's two greatest analytical contributions, let me connect some of his work with that of Hicks. Hicks reduced the general equilibrium of production and exchange of n goods to the following homogeneous-of-degree-zero net demand functions involving prices, $P = (p_1, \ldots, p_n)$

$$0 = -F(P) = -f_j[p_1, \ldots, p_n] \equiv -F[\lambda P]$$

He demonstrated that a unique solution to price ratios, P^*/p_1^*, would be assured if everyone always spent each extra dollar of income in the same way.

In that case, I and others proved that the system would be dynamically stable, in the sense that the following algorithm of price formation would converge to P^*/p^*

$$\dot{P} = (\dot{p}_j) = (-k_j f_j[P] = -KF[P]$$
$$\lim_{t \to \infty} P(t) = P^*/p_1^*, \text{ for any } P(0) > 0$$

Here K is a diagonal matrix with positive, but arbitrary, k_j elements.

Arrow, in collaboration with Leonid Hurwicz of the University of Minnesota, explored global stability when the Jacobian matrix $[\partial f_i/\partial p_j] = F'[P]$ is not symmetric but does have positive off-diagonal elements.

Arrow, in accordance with the new tradition stemming from topological work by A. Wald and J. von Neumann, went beyond the mere counting of equations and unknowns in $F[P] = 0$. The question of the existence of at least one equilibrium solution, P^*, had to be explored in terms of the use of inequalities, usually involving delicate fixed-point theorems of the type developed by Brouwer and Kakutani. Collaborating with G. Debreu, Arrow not only established such existence and

Speaking of Science

A Black Hole in Our Galaxy?

Last week several well-respected astronomers publicly stated that there is good evidence for a black hole in the constellation Cygnus.

For more than a year evidence has been mounting that a certain source of x-rays is a black hole, a region left behind after a very massive star has collapsed and where the gravitational forces are so strong that nothing, not even light, can escape (*Science*, 28 January 1972). Very little new evidence was presented last week for christening the x-ray source named Cygnus X-1 as the first black hole, but on the basis of prior evidence Jeremiah Ostriker of Princeton University said at a meeting of the American Astronomical Society in Pasadena, California, that, if the x-ray source were associated with a certain blue star, "I'd be hard put to say it isn't a black hole."

Although many scientists at the Pasadena meeting were skeptical about the publicity given to an unproven idea, most agreed that a betting man would bet on a black hole.

Apparently Cygnus X-1, like most x-ray sources, is part of a binary star system. Although the x-ray source cannot be seen, it appears to be orbiting about a large blue star. If the blue star is very massive, as its spectral type would indicate, then the x-ray source must be massive and almost certainly must be a black hole. Gravitational theory predicts that almost any compact object with more than twice the mass of the sun must be a black hole. (Lighter compact objects can be neutron stars and white dwarfs.)

But the x-ray source may not be part of the blue star system, because the identification depends on a rather detailed argument about the linkage of three observations: radio, optical, and x-ray. The x-ray observation is crucial because it alone indicates a very compact object, but it is not as precise as the other two measurements. During the last year a shift in the x-ray emissions coinciding with a shift of the radio signal tended to corroborate the linkage. However, there is still some uncertainty whether the blue star and the x-ray source are really companions or not.

Another uncertainty is the true mass of the blue star; because it is not well separated from other stars, the spectral type may not be a good indicator of its mass.

The various announcements at Pasadena certainly did not indicate a consensus that a black hole had been discovered, but participants at the conference noted that many astronomers are investing their energies in further research on the Cygnus X-1 system. Preliminary data on the blue star system may indicate the direction of future investigations. Jerome Kristian of the Mount Wilson and Palomar Observatories and Harding Smith of the Berkeley Space Sciences Laboratory reported helium emission lines coming from the blue star, or possibly from the x-ray source. Emissions from the x-ray source could establish its mass directly, and verify its tentative identification as the first black hole.—W.D.M.

uniqueness theorems for positivistic systems, but also for normative formulations of how a system should optimally function.

I shall briefly refer to Arrow's work in the area of risk and decision theory, as summarized in his collected papers on the subject. In 1952, he stated for the first time the necessity for optimal allocation of risk-bearing of so-called Arrow-Debreu contingent-securities (which pay different returns depending on which one of all possible contingent states of the world materialize).

I conclude with an indication of what is involved in his celebrated Impossibility Theorem, which is to mathematical politics something like what Gödel's 1931 impossibility theorem is to mathematical logic.

Imagine 3 (or more) states: for example, Taft is elected President in 1912, Wilson is elected, Roosevelt is elected. Imagine 3 (or more) individuals, each of whom has a preference ordering of these states. Thus, $(WRT)_1$ means man 1 prefers Wilson to Roosevelt or Taft, and Roosevelt to Taft.

Arrow asks: Given *any* 3 of the $(3!)^3$ choices for $(\ )_1$, $(\ )_2$, $(\ )_3$, how can we define a social preference ordering, call it $(\ )_0$, that obeys a few appealing axioms? (Thus, each man's vote is sometime to count. If Roosevelt dies or lives, *that* should not affect choice between Taft and Wilson. And so forth.)

He then proves by elegant reasoning that it would involve a self-contradiction for there to be a solution satisfying all of these appealing axioms.

Aristotle must be turning over in his grave. The theory of democracy can never be the same (actually, it never was!) since Arrow.

The Scientists' Way

Scholars make their primary contribution through their writings. We judge them as men by their influence on students and co-workers. Both Hicks and Arrow have been blessed in this regard, and have shed blessing.

For sociologists of science, like R. K. Merton, Hicks and Arrow each demonstrate that one need not be at the outstanding university of the moment to make one's scientific mark. Hicks, at LSE and Manchester, helped elevate those places to distinction in economics. Stanford gave Arrow his chance before he was famous. He rewarded it by creating the Stanford school of economic theorists. It says something for academic life that both men were recognized as being deserving of the most prestigious academic posts, and were able to exercise choice among numerous opportunities.

PAUL A. SAMUELSON
Massachusetts Institute of Technology, Cambridge 02139

Notes

1. Sir Roy Allen is said to have told the story of how, when Hicks asked him about determinants—no doubt matrices were still too esoteric—he lent Hicks Netto's little book on the subject, and in three weeks Hicks had worked out the essence of *Value and Capital*, his magnum opus. Even if the anecdote is not literally exact, it is well told.
2. A Hicks bibliography, complete through 1968, appears in J. N. Wolfe, Ed., *Papers in Honor of Sir John Hicks, Value, Capital and Growth* (Edinburgh University Press, Edinburgh, 1968), pp. 531–537. Important items are *Theory of Wages* (1932, 1963), *Value and Capital* (1939, 1946), *The Social Framework: An Introduction to Economics* (1942, 1952, 1960), *A Contribution to the Theory of the Trade Cycle* (1950), *A Revision of Demand Theory* (1956), *Capital and Growth* (1965), *A Theory of Economic History* (1969), and various collections of articles, such as *Essays in World Economics* (1959), and *Critical Essays in Monetary Theory* (1967).
3. A selected bibliography for Arrow would include *Social Choice and Individual Values* (1951, 1963), *Essays in the Theory of Risk Bearing* (1971), *Studies in Linear and Non-Linear Programming* (1958, with co-authors L. Hurwicz and H. Uzawa), *Studies in Mathematical Theory of Inventory and Production* (1958, with co-authors S. Karlin and H. Scarf), *Public Investment, The Rate of Return, and Optimal Fiscal Policy* (1970, with co-author M. Kurz), and *General Competitive Analysis* (1971, with co-author F. H. Hahn).

The 1972 Nobel Prize for Physics

The 1972 Nobel Prize for Physics has been awarded to John Bardeen of the University of Illinois, Leon N. Cooper of Brown University, and John Robert Schrieffer of the University of Pennsylvania for their development of a microscopic theory of superconductivity. Popularly referred to as the BCS theory since it was first put forward in 1957, it has had remarkable success in explaining a wide variety of experimental results, has stimulated new theoretical and experimental studies of superconductivity on an unprecedented scale, and has had an important impact on other fields. The award to Bardeen, who shared the 1956 prize for his role in the invention of the transistor, represents the first time in the history of the Nobel prizes that the same person has received the prize more than once in the same field.

Although the award is frequently shared, the recipients have often worked independently. Such was not the case for Bardeen, Cooper, and Schrieffer, who have frequently emphasized the closeness of their collaborative effort in the Physics Department of the University of Illinois during the years 1955 to 1957.

John Bardeen, the senior member of the group, was 48 at the time of the discovery, and had been awarded the Nobel prize only a few months earlier. Long recognized as one of the world's outstanding solid state theorists, he had come to the University of Illinois from Bell Laboratories in 1951 as a professor of physics and electrical engineering, partly in order to devote more of his time to research on superconductivity. Leon Cooper, 21 years Bardeen's junior, came to Illinois in the fall of 1955 to work as a postdoctoral research associate with Bardeen; his earlier training and experience (as a graduate student at Columbia under Robert Serber and a postdoctoral fellow at the Institute for Advanced Study in Princeton) had been in field theory and nuclear physics. Robert Schrieffer, the junior member of the group, was a third-year graduate student in physics at the University of Illinois and 25 years old in 1957; after his undergraduate degree at the Massachusetts Institute of Technology, he had decided on Illinois for his graduate work in order to have the opportunity to work with Bardeen.

It was this team, a professor, a postdoctoral research associate, and a graduate student, who solved the nearly 50-year-old riddle of the origin of superconductivity. Discovered by Kammerlingh-Onnes in 1911, superconductivity (the ability of the electrons in some metals to exhibit perfect diamagnetism and, once set in motion, to maintain that current-carrying state almost indefinitely) had been the subject of intensive study by many of the theoretical giants of this century, including Bohr, Bloch, Feynman, Heisenberg, Landau, and F. London. This list of outstanding men attests to the importance of the problem. By the same token, its solu-