Nobel Prizes: Four Named for International Award

1. Physics

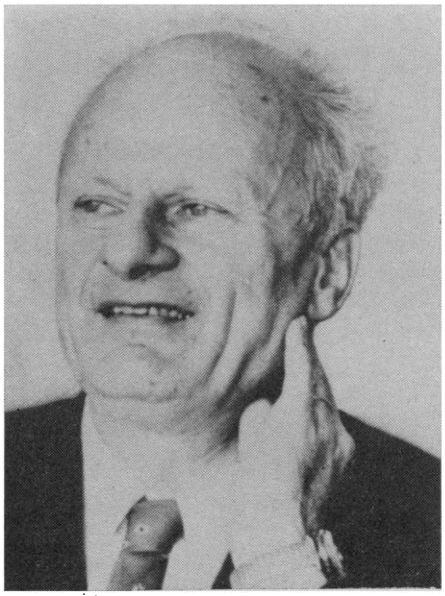
Physicists all over the world will acclaim the award of the Nobel prize to Hans Bethe. It must have been difficult for the Nobel committee to comply with the regulations by singling out one specific achievement as the prize-winning one among Bethe's numerous important contributions to modern theoretical physics. There is hardly any other physicist who has worked as productively as he has at so many different fronts.

His first publications, in the late 1920's, dealt with problems of atomic and solid-state physics. He collaborated with Sommerfeld on problems of electron motion in metals, and he wrote several fundamental papers about electron wave functions in crystals and about the theory of x-ray and electron diffraction. This work contains one of the first applications of group theory to quantum mechanics, involving the use of crystal symmetries for the determination of electron wave functions.

The problem of energy loss of fast particles in matter caught Bethe's interest from the beginning, and he has worked on these questions throughout his life. It is a subject which he unraveled almost single-handedly.

His contributions to quantum electrodynamics are characteristic of his approach to physics: Whenever a new field opens up, he is among the first who apply it fruitfully and establish its validity. When it became clear that the Dirac equation describes the electron pair situation, Bethe and Heitler calculated the pair creation cross sections and the corresponding phenomenon—the Bremsstrahlung—for all angles and energies. They arrived at the well-known formulas which have remained the basic approach to this problem for over 30 years until today. When Lamb and Retherford were able to measure the electromagnetic shift of atomic levels, Bethe was the first to apply the new ideas of renormalization to the problem and give a quantitative account of the observed effect. When more accurate relativistic calculations of the interaction of two charged fermions became necessary, Bethe and Salpeter developed a method which allowed calculation to a high degree of approximation. Some results of this method were impressively confirmed by measurements of the positronium spectrum.

Bethe's contributions to nuclear physics make up the largest part of his work. These began in 1934 with his treatment of the proton-neutron system. In collaboration with R. E. Peierls he worked on neutron-proton scattering and on the properties of the deuteron. Fifteen years later he introduced the useful concept of "effective range" into the theory of particle scattering. Bethe was the first to come up with quantitative calculation of level densities in nuclear spectroscopy, in 1936, and has contributed to this problem ever since. Bethe's strength was that of finding simple and general ways to deal with complicated situations. In a paper in 1940 he introduced the "continuum" theory of compound nucleus formation, which later on was widely used and led to the "clouded crystal ball" model. The same direct treatment of a nucleus as a strongly absorbing "black" sphere resulted in his calculations, with G. Placzek, of nuclear "shadow-scattering."



Hans A. Bethe

When the concept of the meson was introduced into nuclear physics, Bethe was one of the first to study the representation of nuclear forces by meson exchange. He worked intensively on the interpretation of experimental results pertaining to meson-nucleon scattering in terms of phase shifts. When Bethe works in a new field, he accumulates and digests the knowledge of the day and presents it in his own special form for the daily use of other, less able physicists. Today we find on the desk of everyone who works on meson physics the two volumes of *Mesons and Fields,* which he wrote with S. Schweber and F. de Hoffmann.

Lately his interest has been caught by the problem of the properties of nuclear matter—that is, the substance of which nuclei are made. This complicated question was opened up by K. Brueckner; Bethe took this problem into his own hands and applied to it his powerful gifts of synthesis by making use of all knowledge and experience which exists in this field. The results are correspondingly impressive.

The most striking payoff, however, of his thorough and encyclopedic knowledge of nuclear physics appeared in 1938 in the form of a paper entitled "Energy Production in Stars." This is the contribution for which he received the Nobel prize. Here his phenomenal knowledge of all details of nuclear reactions enabled him to find cyclic nuclear processes which take place in the interiors of stars and which produce the energy that keeps normal stars hot for billions of years. The idea itself, that nuclear reactions produce stellar energies, was not a new one. But Bethe was the first to introduce the carbon cycle as one of the important energy sources, and the first to estimate quantitatively the reaction rates and the energy production. With this paper he opened up a new branch of nuclear science, to which he himself contributed a large number of papers. He applied nuclear physics to phenomena for which it is essential. The natural place in the universe for nuclear processes to occur is in the interior of stars. Nuclear physics on earth is restricted to borderline phenomena, such as natural radioactivity or man-made artifacts, particle accelerators, or nuclear reactors. Bethe put nuclear physics in its true place.

Bethe's phenomenal depth of knowledge of physics in general gave him a special proficiency in applying the ideas and methods of one field to another, and in solving problems and undertaking tasks which could not have been tackled before. This is why he could contribute so much to the new fields of technology that have recently been opened up. He contributed much to the development of microwave radar in 1942 and to the problems of nuclear fission and its application. At Los Alamos his thoroughness, encyclopedic knowledge, and quick understanding were invaluable. Here he brought to bear not only his great strength in nuclear physics but his ability and experience in hydrodynamics and electromagnetic theory.

In 1958 Bethe served as a member of the United States delegation to the first International Test Ban Conference in Geneva. Solid experimental information was very scarce, particularly about underground explosions. He became an expert, quite naturally, and often produced solutions to perplexing problems from one day's meeting to the next.

Bethe also worked on the problems of reentry of missiles and rockets into the earth's atmosphere, and with characteristic thoroughness studied the excitations and ionization of gas in the boundary layer. What counted so much in his work on these problems was his deep understanding of the fundamental processes which cause the specific properties of materials under unusual conditions.

Hans Bethe was born in Strassbourg in 1906, and received his Ph.D. in 1928 in Munich, as a student of Sommerfeld's. He worked as a research fellow and instructor at several German universities until 1933, when the political situation forced him to leave Germany. After 2 years' work in England he came to the United States as professor at Cornell University, and he has stayed there ever since.

Every paper of Bethe's (there are almost 300 titles) bears the characteristic marks of his insight and his special way of attacking problems. He differs from most of us in his universality and his encyclopedic knowledge. Three monumental review articles written within a period of 5 years give us proof. The first is a review of one- and two-electron problems, in the *Handbuch der Physik*; the second, written with A. Sommerfeld, and appearing in the same *Handbuch,* deals with electrons in metals; the third is a group of three articles on nuclear physics, written with the collaboration of R. F. Bacher and M. S. Livingston and published in the *Reviews of Modern Physics.* These articles are not reviews in the ordinary sense of the word. They are systematic recreations of the knowledge of the time, supplemented by original work wherever there were gaps and omissions in the current knowledge, and each bears the strong imprint of Bethe as the principal author. The work of other physicists is redone, reformulated, and often corrected, so that the review article has its own unity and clarity, in the style of Bethe. The first of these reviews was reprinted in 1959. This new edition (prepared in collaboration with Salpeter) is almost identical with the original version. Not much, apart from new experimental results and some refinements in theory, had to be added in order to bring it up to date after 25 years.

The three great reviews are characteristic of Bethe's broad knowledge, but they by no means give a complete picture of it. His interests cover a much broader horizon. Bethe steps in productively whenever a new physical phenomenon is discovered. He is among the first with an exhaustive explanation based on the latest theoretical ideas; or, whenever a new theoretical method is conceived, he is among the first with an exhaustive application to some still unexplained observations. He has his own simple and direct approach to theory and experiment, and his trademark is thoroughness. It is all "handmade." He does not take the experimental results for granted. He analyzes them himself, often making corrections for effects that had been overlooked, and taking great pains in doing the numerical work, in fitting curves, and in estimating errors.

There is a large community of Bethe students, collaborators, and friends all over the world. We all know and value his wisdom, his patience, and his readiness to help in any situation, be it a difficult problem of physics or a personal or political one. His warm, straightforward, and simple approach to any human or scientific question has given support and confidence to many people. Bethe never refuses his support when he can give it. Unfortunately for him, but fortunately for others, there have been too many occasions on which his help has been solicited and received. He has sacrificed many pleasures, a good deal of his own scientific work, and too much of his nervous energy, for the good of all of us. He has served in Washington on many committees because he has been able to contribute to many. We must be deeply grateful to him for this great sacrifice, which for him was a matter of course, since his sense of duty toward society is so deeply ingrained that he wasn't even aware of its being a sacrifice.

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2. Chemistry

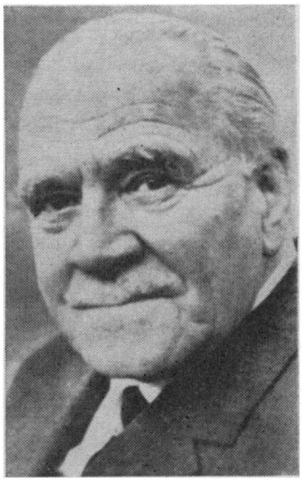
The Nobel prize in chemistry has been given to Manfred Eigen, Ronald Weyforth Norrish, and George Porter jointly in recognition of important new developments in the study of very fast chemical reactions. The procedure followed, in every case, is to shift systems from equilibrium by an energy pulse of as short duration as possible and then to follow the subsequent change as the systems return to an equilibrium state.

In the case of the flash photolytic experiments of Norrish and Porter, the pulse of energy is so intense that many excited-state species are produced, with a consequent plethora of reactions occurring far from equilibrium. With Eigen's experiments, on the other hand, the perturbation of the chemical system is deliberately made small and the resulting reaction kinetics are those of a system in its ground electronic state, displaced only slightly from equilibrium.

Manfred Eigen's share in the chemistry prize is in recognition of his invention and application of "relaxation techniques" of measuring rates of rapid reactions, primarily in liquids. Many interesting inorganic, organic, and biochemical reactions in liquids have half reaction times shorter than a millisecond, and their rates are consequently immeasurable by rapid mixing techniques. Eigen made the ingenious suggestion in 1954 that, if such a chemical

George Porter

Manfred Eigen



Ronald G. W. Norrish

system already at equilibrium were perturbed slightly by a rapid change in temperature, hydrostatic pressure, or electric field intensity, the resulting first-order change in chemical concentrations with time could be followed spectrophotometrically or conductometrically to give a chemical time constant for the system, commonly referred to as the relaxation time τ. The experimental value for relaxation time could then be combined mathematically with the known initial concentrations to give specific rates for both the forward and the backward reactions in the chemical equilibrium. A classically simple illustration of the fruitfulness of this suggestion is Eigen's investigation with Leo DeMaeyer, in 1955, of the reaction

$$\mathrm{H^+ + OH^-} \overset{k_R}{\rightleftarrows} \mathrm{H_2O}$$

in pure liquid water. Applying an electric field of the order of 10^5 volts per centimeter to this sample system, they measured a conductometric relaxation time of ~ 37 microseconds which, combined with $[\mathrm{H}+] \approx [\mathrm{OH}-] \approx 10^{-7}M$ and $K_a = 10^{14}/55.5$ in the expression

$$k_R = \frac{1}{\tau} \langle [\mathrm{H^+}] + [\mathrm{OH^-}] + K_a \rangle^{-1},$$

yields a value of $k_R = 1.3 \times 10^{11}$ liters per mole per second. This particular experiment is quite representative of Eigen's work in that it established a bench mark of enormous utility in fields as diverse as radiation chemistry and enzyme kinetics; it was executed with the assistance of DeMaeyer, a gifted Belgian physical chemist with an unusual facility for electronics, and the theoretical ramifications of the experiment were explored exhaustively and with great originality by Eigen in subsequent papers.

Eigen was born 9 May 1927 in Bochum, Germany, the son of Ernst and Hedwig Feld Eigen. He was trained in physics and chemistry at the University of Göttingen. During World War II his studies were interrupted briefly for service with an antiaircraft gun crew. He received his doctor of natural science degree from the University of Göttingen in 1951, was on the staff of the University's Institute for Physical Chemistry until 1953, and then joined the Max Planck Institute for Physical Chemistry, in Göttingen, where he has remained ever since. His earliest research was on extensions of the Debye-Hückel theory of electrolyte solutions; the results of this research are still frequently cited. With his delivery of his first paper on relaxation methods, at the Faraday Society Discussions on Fast Reactions in 1954, he opened his attack on the measurement of fast reactions in condensed phases that, to date, has yielded important insights on diffusion-controlled reaction rates in liquids and solids, on the kinetics of ligand addition to solvated metal ions, on the mechanisms of the discrete steps in several enzyme-catalyzed reactions in vitro, and on the mechanism of the helix-to-random-coil transformation in polypeptides.

Eigen has authored or coauthored almost a hundred scientific papers. His students and postdoctoral associates have produced many more which, though they do not bear his name, owe a great deal to his inspiration and incisive criticism. Most of Eigen's own papers are milestones in the sense that they break open completely new fields for the application of relaxation techniques. Impressive cases in point are his 1955 paper, with Schoen, on dissociation-field-effect relaxation-method studies of diffusion-controlled protolytic reactions in aqueous solutions; a paper, with Czerlinski in 1959, introducing the now generally used Joule heating-temperature-jump technique; two papers in 1962, with Tamm, that elucidated the discrete reaction steps causing sound absorption in 2-2 electrolyte solutions; and a paper on the kinetics of keto-enol tautomerism written with Ilgenfritz and Kruse in 1965.

Those who have worked with Eigen find some of his most striking characteristics to be his cheerfulness, his flair for the dramatic in presenting his research (in impeccable English), his generosity with his time, and his almost inexhaustible energy. When he is not on one of his frequent speaking trips he usually reaches his laboratory by midmorning and frequently works until 2 a.m. at his home after a late supper. He maintains this taxing schedule in spite of generally less than robust health. Eigen is an accomplished musician, playing the piano exceptionally well. Two of his other interests of long standing are hiking and the gathering of wild mushrooms. Happily, he is expert in this latter hobby also. He and his wife Elfriede and their two attractive children—a teen-age son and a 6-year-old daughter—live in a beautiful home in the outskirts of Göttingen.

In recent years Eigen has been widely honored both here and abroad with guest lectureships, medals, and honorary degrees. He was elected a foreign associate of the U.S. National Academy of Sciences in 1966. At present he serves as an adviser to the German government on science policy, a responsibility that he particularly appreciates, having long promoted major reforms in the German system of higher education. He is also the director of the Max Planck Institute that he joined in 1953, and he looks forward to assuming the directorship of a new Max Planck Institute for Biophysical Research, to be constructed in Göttingen in the near future.

Ronald Norrish was born 9 November 1897 in Cambridge, England, and was educated at the Perse Grammar School in Cambridge. He obtained a scholarship to Emmanuel College, Cambridge, in 1915. World War I took him to France, where he served as a lieutenant in the Royal Field Artillery. He was graduated from Cambridge in

1921, received his Ph.D. in 1924, and was elected to a fellowship of Emmanuel College. He became University demonstrator in physical chemistry in 1926. His studies for the Ph.D. under Sir Eric Rideal launched his career in photochemistry and chemical kinetics. In 1937 he became professor of physical chemistry and director of the department of physical chemistry in the University of Cambridge, positions from which he retired in 1965.

Very early he studied primary photochemical reactions of nitrogen peroxide, aldehydes, ketones, and their near relatives the ketenes and diazomethane. He found that carbonyl compounds are photolyzed by two routes. One route yields free radicals; the other, stable molecules. All these compounds have since been used as sources of free radicals for the initiation of combustion and polymerization.

Norrish elucidated the mechanisms of combustion of methane and ethylene, which involve formaldehyde as an intermediate. Ultraviolet light acting on the aldehyde intermediate in these oxidizing systems speeded up the reaction, resulting in some cases in explosions.

He made extensive studies of the polymerization of vinyl compounds and other substances, and exhaustively studied the effect of cross-linking by divinyl compounds and effects of solvents on the kinetics of polymerization.

After World War II, Norrish and George Porter and their colleagues began their study of very fast reactions, using flash photolysis and kinetic spectroscopy. The half-life of these reactions extended from the microsecond through the millisecond range. Their technique involved flashes of light of such power as to instantly dissociate the reactant species into radicals or atoms. Use of a second, weaker flash, triggered electronically at microsecond or millisecond intervals after the first, enabled them to record the spectra of the very reactive short-lived intermediates. By varying the times between the first flash and the subsequent ones they could measure the growth and decay of the free radicals and work out the reaction mechanisms.

Gases have such low heat capacities that a flash can raise them to very high temperatures. Thus an adiabatic shock can be generated which, in appropriately chosen systems, can cause an explosion in which the reactive intermediate can be studied throughout the course of the reaction. For example, Norrish and his co-workers studied in this way the explosive combustion and the pyrolysis of hydrogen, hydrocarbons, ammonia, phosphine, and hydrogen sulfide. By adding diluents to gaseous or liquid systems, they could control the temperature and observe the reactions. In this way they studied the reactions of oxygen atoms derived from ozone, and the relaxation of gaseous molecules in a high state of vibration. They successfully applied the method of kinetic spectroscopy to the study of polymerization and photolysis in solution.

Using the flash photolytic technique, Norrish has provided an interesting explanation for the effectiveness of lead tetraethyl in repressing engine knock. It seems that molecular lead oxide in the gas phase, and not smoke, is the deactivating agent. This is substantiated by the fact that tin tetraethyl yields a less volatile oxide that does not delay detonation but does produce a great deal of smoke.

George Porter was born in Stainforth, Yorkshire, in 1920. He studied at the University of Leeds and then, after service in World War II, at Emmanuel College, Cambridge. From 1952 through 1954 Porter was assistant director of the University of Cambridge's department of physical chemistry, which Norrish headed. In 1955 he moved to the University of Sheffield, where he remained for 9 years, and since last year he has been professor of chemistry and director of the Royal Institution in London.

We found it particularly interesting to visit with all three Nobel laureates at the Fifth Nobel Symposium on Fast Reactions, held in Stockholm in August 1967. All three are strikingly personable, attractive individualists, and they were the focus of many of the interesting discussions both at the scheduled meetings and at the many informal discussions around the dinner table.

The fact that all three Nobel laureates have attractive, outgoing personalities should impress those youthful students of science who suppose that in a scientific career they can find refuge from the commercial world of salesmanship. The great impact all three men have had on the field of chemical kinetics is attributable in no small measure to their gifts of exposition, which have sold many other physical chemists on the use of their perturbation techniques, as well as to their unusual talents for scientific invention.

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Research in Japan: U.S. Army Grants Cause Controversy

Who would have guessed that what the U.S. Army described as a "goodwill gesture" last year would snowball into a controversy that may undermine U.S.-Japanese scientific cooperation?

At the time, the Army's action seemed praiseworthy. The Physical Society of Japan was sponsoring an international conference on semiconductors in Kyoto last September and was short of travel funds. According to Japanese newspaper accounts, a former Tokyo University president arranged a grant of $8000 from the U.S. Army to pay the travel expenses of American participants. The Americans were able to attend, and international cooperation, it seemed, had been fostered.

But within a few months the Army's gesture had provoked a debate over military support of basic research in Japan. The *Asahi Shimbun*, the largest and most influential daily newspaper in Japan, picked up complaints from the scientific community and on 5 May published a page-one top-play story "disclosing" the Army's role in subsidizing the semiconductor conference. The paper also pointed out that the Army was making research grants to Japanese scientists. Soon elements of the press, opposition political parties, student groups, and assorted scientists, educators, and left-wing intellectuals began howling for an end to "military" research.

The ensuing controversy, though little noticed in this country, was deemed critical enough to warrant discussion at the highest governmental