Agogino, C. V. Haynes, Jr., "The succession of Paleo-Indian cultures at Hell Gap, Wyoming," in press.

8. R. Stuckenrath, Jr., *Quaternaria* **8**, 75 (1966).
9. J. L. Coe, in *Trans. Amer. Phil. Soc.* **54**, 6 (1964); B. J. Broyles, *W.Va. Archeol.* **19**, 1 (1966).
10. J. Montané, *Science* **161**, 1137 (1968).
11. W. S. Laughlin, in *The Bering Land Bridge*, D. M. Hopkins, Ed. (Stanford Univ. Press, Stanford, Calif., 1967), p. 409; D. D. Anderson; *Sci. Amer.* **218**, 24 (1968); R. A. McKennan and J. P. Cook, "Proc. Int. Anthropol. Congr., 8th, 1968," in press; R. E. Ackerman, *Wash. State Univ. Lab. Anthropol. Rep. Invest.* **44**, 55 (1968).
12. G. F. MacDonald, *Anthropol. Pap. Nat. Mus. Can.* **16**, 1 (1968).
13. C. V. Haynes, Jr., and E. T. Hemmings, *Science* **159**, 186 (1968).
14. J. E. Fitting, J. DeVisscher, E. J. Wahla, *Anthropol. Pap. Univ. Mich.* **27**, 1 (1966).
15. E. N. Wilmsen, *Amer. Antiquity* **33**, 156 (1968); *Science* **161**, 982 (1968); G. C. Frison, *Amer. Antiquity* **33**, 149 (1968).
16. A. L. Bryan, *Current Anthropol.* **10**, 339 (1969).
17. W. S. Broecker and W. R. Farrand, *Bull. Geol. Soc. Amer.* **74**, 795 (1963); F. T. Thwaites and K.. Bertrand, *ibid.* **68**, 831 (1957).
18. R. J. Mason, *Anthropol. Pap. Univ. Mich.* **11**, 1 (1958); G. I. Quimby, *Indian Life in the Upper Great Lakes, 11,000 B.C. to A.D. 1800* (Uniy. of Chicago Press, Chicago, 1960).
19. R. Gruhn, *Occasional Pap. Idaho State Univ. Mus.* **6**, 1 (1961); ———, *Tebiwa* **8**, 57 (1965); A. L. Bryan, *Occasional Pap. Idaho State Univ. Mus.* **16**, 1 (1965).
20. L. S. Cressman, personal communication.
21. R. Fryxell, T. Bielicki, R. D. Daughtery, C. E. Gustafson, H. T. Irwin, B. C. Keel, G. S. Krantz, *Proc. Intern. Anthropol. Congr. 8th, 1968*, in press; *Amer. Antiquity* **33**, 511 (1968); new radiocarbon age determinations indicate that the lowest occupation levels are only 10,200 years old (R. Fryxell, personal communication).
22. F. Wendorf and A. D. Krieger, *Amer. Antiquity* **25**, 66 (1959). If the recent finds of human bones near Laguna Beach, California, could be validated by stratigraphic documentation, the recent dating of the bones by R. Berger and W. F. Libby [*Radiocarbon* **11**, 206 (1969)] as 17,150 ± 1470 B.P. (UCLA-1233A) would make them the oldest human bones known from the New World.
23. C. V. Haynes, in *Pleistocene Extinctions: A Search for a Cause*, P. S. Martin and H. E. Wright, Jr., Eds. (Yale Univ. Press, New Haven, Conn., 1967), p. 267.
24. C. Irwin-Williams, in *ibid.*, p. 337; H. E. Malde, unpublished data (1968).
25. J. L. Lorenzo, *Bol. Inst. Nac. Anthropol. Hist.* **29** (1967); C. Irwin-Williams, *Paleo-Indian Inst. East. N. Mex. Univ. Misc. Publ.* **1**, 1 (1967); ———, *Amer. Antiquity* **34**, 82 (1969).
26. L. Mirambell, *Bol. Inst. Nac. Anthropol. Hist.* **29**, 37 (1967); C. V. Haynes, *ibid.*, p. 49.
27. A. D. Krieger, in *Prehistoric Man in the New World*, J. D. Jennings and E. Norbeck, Eds. (Univ. of Chicago Press, Chicago, 1964), p. 23.
28. L. S. B. Leakey, R. DeE. Simpson, T. Clements, *Science* **160**, 1022 (1968).
29. From personal observations at Calico Hills, I cannot agree that there is an "absence of intense weathering" of the deposit, as stated in R. Berger and W. L. Libby, *Radiocarbon* **11**, 206 (1969).
30. K. P. Oakley, *Man the Tool-Maker* (Univ. of Chicago Press, Chicago, 1957), pp. 9–19.
31. C. V. Haynes, Jr., and G. A. Agogino, *Amer. Antiquity* **31**, 812 (1966).
32. D. M. Hopkins, in *The Bering Land Bridge*, D. M. Hopkins, Ed. (Stanford Univ. Press, Stanford, Calif., 1967), p. 24.
33. H. Müller-Beck, *Science* **152**, 1191 (1966); F. Wendorf, *Amer. Naturalist* **100**, 253 (1966).
34. C. V. Haynes, Jr., *Science* **145**, 1408 (1964); J. J. Hester, *Congr. Int. Amer. 36th* (1966), vol. 1, p. 129.
35. C. V. Haynes, Jr., in *Pleistocene and Recent Environment of the Great Plains*, W. Dort, Jr., and A. E. Johnson, Eds. (Univ. of Kansas Press, Lawrence, in press); *Sci. Amer.* **214**, 104 (1966); F. E. Green, *Amer. Antiquity* **29**, 164 (1963).
36. W. J. McGee, *Amer. Anthropol.* **2**, 301 (1889).
37. R. B. Morrison and J. C. Frye, *Nev. Bur. Mines Rep.* **9**, 1 (1965).
38. C. E. Borden, *East. N. Mex. Univ. Contrib. Archeol.* **1**, 55 (1968).
39. My research in Quaternary geochronology is supported in part by the National Science Foundation (grant GA-1288), the National Geographic Society, and the Institute for the Study of Earth and Man. The suggestions of F. Wendorf and E. W. Haury for improving the manuscript are greatly appreciated.

NEWS AND COMMENT

Nobel Laureates in Economics, Chemistry, and Physics

1. Economics

That Ragnar Frisch and Jan Tinbergen were both on the short list of candidates for the first Nobel prize in economics was well known and fully anticipated. The only surprise element in the final announcement of the prize was that the award was joint. This choice was by no means illogical, but the two men had not worked together on their greatest contributions although they were of the same generation and pioneered together in establishing the subjects of econometrics and mathematical economics. Their professional reputations are worldwide, and they have long stood as giants in their home countries, in leading academic centers, and in world gatherings of scholars.

During the 1920's, and especially in the 1930's, the quantitative approach to economics through the use of mathematics and statistical method began to flower. Acceptance of this approach was resisted in England and America, but Norway and Holland were renowned for researches along these lines because of the dominating influence of Frisch and Tinbergen and their students, many of whom are leaders in the present generation.

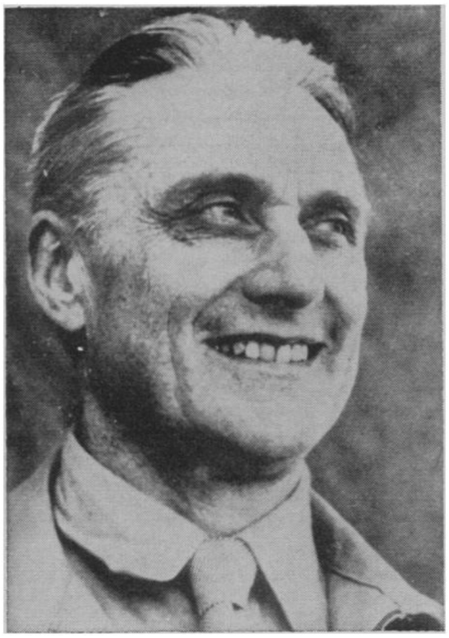
Econometrics grew in the United States. Before World War II, several of the leading figures were European immigrants. The Econometric Society was founded in 1930 by a mixed group of Europeans and Americans, some of the people being drawn from outside economics. Ragnar Frisch was instrumental in organizing the founding group.

It was not until the middle of the 1950's that econometrics was able to flourish in American universities. By then, textbooks had become available; several leading centers offered advanced courses in the subject and provided professorships in econometrics.

There is some confusion over the meaning of "econometrics" as a discipline, and it is worth while considering a careful definition, for this brings out more clearly the separate contributions of the two prizewinners and the relationships between their work. Econometrics is measurement in economics, where that measurement is applied to the mathematical formulation of economic theory and carried out according to the principles of mathematical statistics.

Mathematical economics exists apart from econometrics. It is simply the analysis of economic theory through the medium of mathematics. It is often deterministic theory and is not always put in measurable terms. Econometrics, on the other hand, requires a stochastic formulation of economic life and deals with measurable (or potentially measurable) magnitudes. Mathematical economics generates the hypotheses about the structure of an economy or its subsectors, while econometrics undertakes to test these hypotheses and estimate the implied interrelationships. Much of econometric theory is concerned with optimum methods of making statistical inferences within the framework of a mathematical statement of economic relationships.

The Econometric Society was founded jointly by people interested in mathe-



Ragnar Frisch

matical economics and in econometrics. Although university classes and appointments distinguish sharply between these two fields now, the Society welcomes both types. They both serve to build a scientific foundation for economics, and the complementarity of Frisch and Tinbergen is clearly seen in this light.

Ragnar Frisch has been a prolific contributor to many branches of economics, statistics, and applied mathematics. His greatest individual contributions have been to the mathematical theories of dynamic models of the whole economy, the theory of production, the theory of consumer behavior, the theory of index numbers, and the theory of planning. He has not neglected econometric theory or applied statistical analysis. He made important contributions to correlation theory and multivariate statistical analysis of economic data and built a general methodological system in that subject. From that work, one basic concept remains—multicollinearity. This is the tendency of many economic variables to move together as a result of common trends, cycles, or other joint characteristics. The modern theory of econometrics does not follow the general system of analysis originally laid down by Frisch but was strongly directed into its present course by one of his greatest students, T. Haavelmo.

Among Frisch's many books, articles, and unpublished memoranda, one of the most elegant is a paper entitled "Propagation problems and impulse problems in dynamic economics." In this paper he shows how leading aggregative concepts in economics (total production, total consumption, total investment, and so on) can be interrelated in a system of simultaneous dynamic equations. The solution of this system (of difference-differential equations) reveals the process known as business cycles. This is the propagation mechanism. In the case Frisch was considering there was strong dampening. The impulse problem arises from random or isolated shocks imposed on the equations of economics. Frisch showed how the impulse mechanism keeps economic fluctuations alive when the propagation mechanism is a damped process. He built on the basic contributions of the Russian mathematician-economist E. Slutsky and the English statistician G. Yule.

Frisch worked out much of the mathematical theory of interrelationships among goods and prices in production and consumption. He estimated statistical production functions for individual plants, systems of demand equations, and index members of the cost of living. In applied mathematics he wrote basic papers on probability theory, the solution of difference-differential equations, the inversion of moving averages, the solution to linear programming problems, and many other matters. He was editor of *Econometrica* during most of its early years.

In World War II he was imprisoned by the Nazis; after his release he turned to the analysis of world trade matrices, planning systems, social accounting systems, and the theory of linear programming. Occasionally he contributed to the kinds of studies that he had opened up during the prewar years. The Oslo Model for a statistical-economic planning system is the product of his teaching over many years.

If Frisch's main contributions were in mathematical economics, with an occasional venture into econometric theory or applied econometrics, Tinbergen's were principally in applied econometrics, and dealt occasionally with problems in mathematical economics. Tinbergen, too, has been a prolific writer. He has treated statistical models of entire economies, the mathematical analysis of economic cycles, the theory of income distribution, the theory of economic growth, the measurement of elasticities of substitution, the theory of economic planning, and the theory of economic development.

Jan Tinbergen

Tinbergen entered the field of economics from a background of scientific training. His work reflects this transition. At an early stage, in the 1930's, he published papers on the modeling of an aggregative economy in the form of a system of simultaneous dynamic equations, and set out to measure the parameters of such systems from actual economic data. He built a system for the Netherlands and then produced an extremely important study of the United States along these lines for the League of Nations. Having formulated a mathematical model of an economy, with statistically estimated coefficients, Tinbergen analyzed its cyclical properties through the solution to the corresponding system of finite difference equations. In the language of Frisch's famous paper cited above, Tinbergen studied the propagation mechanism of the system. Modern econometricians are paying increasing attention to the impulse problem, but they are able to do so because of their use of the computer, which was not available to Tinbergen for these studies.

The League of Nations was justifiably concerned with the economic state of the world during the Great Depression and had Tinbergen make statistical tests of economic theories of the cyclical mechanism, studies that paralleled the well-known work of G. Haberler on alternative cycle theories. In the course of his work, Tinbergen constructed a large-scale mathematical statistical model of the U.S. economy. This has served as the main stimulus for extensive model building in most of the major countries of the world in recent years.

The original Tinbergen model of the U.S. economy was sophisticated from the point of view of economics and used the best known statistical techniques then available. It would not serve as a model of today's economy or compete in that respect with the models now available, but it did inspire and lay the groundwork for today's models. It also dramatized the need for a specialized branch of mathematical statistics to deal with the kinds of inference problems that are peculiar to economics. The architects of the modern theory of econometrics were Frisch's student T. Haavelmo, A. Wald, J. Marschak, and Tinbergen's student T. Koopmans. Their ideas would have been directly applicable to Tinbergen's model-building efforts for the League of Nations had they been available at that time.

Tinbergen's work formed the basis for Dutch government planning from model projections just after World War II, and the Central Planning Bureau was initially directed by Tinbergen. The Dutch government, through Tinbergen's inspiration, has made systematic and formal use of econometric models in its planning, budgeting, and policy actions. Many new contributions to econometric theory and application have grown out of the intensified activity in Holland that has been associated with building and maintaining the Dutch models. In a sense, all members of the army of econometricians are Tinbergen's students. Some of his outstanding students or disciples are leading professors in American universities.

After World War II, Tinbergen worked on a number of separate problems, but his most noteworthy writings were those on the use of models as tools for economic planning policies. He introduced the ideas of "targets" and "instruments." The former are among the dependent variables of a free unplanned system. If the policy maker's goal can be defined in terms of target values for these variables, he can try to reach these goals by finding values for "instrument" variables that would lead there. The "instruments" are independent variables. Tinbergen turned the usual problem on its head. Instead of finding dependent variables associated with given values of independent variables, he found values of independent (instrument) variables associated with dependent (target) variables. These concepts, studied within the context of a statistical model of the economy, became important planning devices to show how to choose instrument values.

Tinbergen later extended these and some earlier ideas on the building of longer-term growth models to the problems of developing economies.

By coincidence, a conference is being held in Cambridge, Massachusetts, this month to study cyclical properties of leading U.S. econometric models—the Wharton-Econometric Forecasting Unit Model, the Office of Business Economics Model, the Brookings Model, and the Federal Reserve–M.I.T.–Pennsylvania Model. In many respects all these models are in the tradition of Tinbergen's pioneering models of the U.S. economy. They are of comparable size and complexity, although some are larger. They all pay substantial attention to money market phenomena, and this is one of Tinbergen's special contributions; he had tried to capture the influence of the security markets in the U.S. expansion and decline of the 1920's and 1930's in his League of Nations model. Of course they are improvements on the Tinbergen model in that they use better statistical data, more intricate economic theory, and more powerful methods of parameter estimation, and exploit the power of the computer in making more detailed analysis of the dynamic properties of the systems. At the conference there will be, in the tradition of Tinbergen, direct calculation of the characteristic roots of the propagation parts of the systems, but there will be more emphasis on numerical simulation without approximate linearization.

As the discussion of the conference will doubtless reveal, the most interesting dynamic properties of modern econometric models emerge from the impulse part of the system. Stochastic simulations in the spirit suggested by Frisch will draw upon the potential of the computer to show cyclical fluctuations that arise from the cumulation of random shocks.

The two principal leads inherited from the work of Frisch and Tinbergen will dominate the research presentations at the November conference, but the influence of these two men on contemporary and future economic research is, and will be, much more widespread. Econometric research on demand and the construction of price indexes will draw upon Frisch's analysis of consumer behavior, especially on complete systems of demand functions. Similar research on the estimation of production relationships will follow his lecture notes on production theory, which have recently been published. His greatest influence, outside cyclical analysis, will be on the construction of planning systems. These systems may be significant to mathematical planning in the socialist countries.

Tinbergen's influence, apart from his role in the general expansion of econometric model construction, will be reflected in the adoption of rational planning techniques (techniques based on the use of targets and instruments) in the industrial countries and in the use of his aggregative type models for charting the course of development in the emerging nations of Africa, Asia, and Latin America.

Most industrial countries of the world now have working econometric models that are being used for forecasting and policy analysis. Where such models do not yet exist, they are being constructed. In the developing nations there is great interest in this subject, and some first attempts at building development models have been made in the United Nations, at many academic centers, and in research bureaus. Tinbergen first demonstrated the plausibility of being able to construct such models; now the idea has spread to all parts of the world. Much further development of this area of research is yet to come.

The professional achievements of the two new prizewinners have been stressed here, but their interests and accomplishments extend beyond the narrow reaches of their chosen fields of specialization. Frisch has for many years been a close student of bee populations as well as a producer of fine honey. He has written for publication in popular media on a wide variety of social and political issues. Tinbergen has been a public servant and man of peace. He too is an astute observer of society. He has served mankind in almost every part of the world.

Economists, especially econometricians and mathematical economists, can be proud of their prizewinning colleagues. The Nobel Committee made magnificant choices for the first prize in economics.

LAWRENCE R. KLEIN
Department of Economics, University of Pennsylvania, Philadelphia

2. Chemistry

Conformational analysis has changed the face of chemistry. It has lifted out of the chemical literature the flat formulas of the 1930's and 1940's and has replaced them with the three-dimensional structures by which we view molecules in the 1950's and 1960's. By now, conformational ideas have invaded the elementary chemistry textbooks. Thus it comes as no surprise that the Nobel Prize in Chemistry this year has been awarded to Derek H. R. Barton of the Imperial College of Science and Technology (London) and Odd Hassel of the University of Oslo "for developing and applying the principles of conformation in chemistry." The significant work was done by Hassel in the period from 1930 to 1955 and by Barton in the period 1950 to 1960. Both men developed the ideas of conformational analysis from the behavior of saturated six-membered rings, and they revolutionized chemical thinking with respect to these structures. Since six-membered saturated (or near-saturated) rings occur in all steroids, the great majority of terpenes, numerous alkaloids, most carbohydrates, and a number of important synthetic chemicals, the vast importance of the concepts is immediately apparent.

What is conformation and what is conformational analysis? Conformational analysis has been defined by Barton himself as "the correlation of preferred shapes or conformations of molecules with their physical and chemical properties." Conformation was defined in one of the daily papers reporting on the Nobel Prize as "the way molecules shape up to do business with other molecules." This popularization may do justice to the work of Barton, but not to that of Hassel whose research has involved the probing of the relation of conformation to physical properties—in other words, "the way molecules shape up when they are isolated." The two shapes, that of the resting molecule and that of a molecule in the course of reaction, are often not the same. Most workers in the field use "conformation" as meaning "the three-dimensional arrangements of a molecule possible by virtue of rotation about single bonds." This definition, while perhaps not universally agreed on, does, with minor modifications, cover most of the work in the field of conformational analysis, including that of the 1969 Nobel laureates.

In order to understand the importance of conformational ideas and the exact contribution that Barton and Hassel have made to the field, one must go back in the history of chemistry about 80 years. In discussing the stability of rings, Sachse, in 1890, pointed out that two perfectly angle-strain-free forms of cyclohexane (the six-membered carbon ring) were possible: one chair-shaped and rigid, the other flexible and sometimes boat-shaped. This hypothesis was correct; but Sachse, not realizing the ease with which rotation about single bonds (and therewith inversion or "flipping" of the chair) can occur, drew some erroneous and experimentally disprovable conclusions from it. As a result, his hypothesis lay dormant. In a popular textbook in 1905 it was stated that cyclohexane should better be thought of in its "average" planar form, and this view persisted in the minds of most chemists until the appearance of Barton's revolutionizing paper [*Experientia* **6**, 316 (1950)].

Conformational ideas did not remain completely unused in the interval. Mohr revived Sachse's hypothesis in 1918, and W. Huckel, in 1925, found strong support for it by isolating two (*cis* and *trans*) decahydronaphthalenes (two fused six-membered rings) of which the *trans* isomer was the more stable. In the 1920's and 1930's Boeseken, in Delft, applied three-dimensional thinking in sugar chemistry; Bilicke, at Caltech, saw the chair form in x-ray diffraction patterns of hexachlorocyclohexanes; and Kohlrausch, in Graz, recognized two types of bonds in the chair (now called equatorial and axial, according to an agreement in 1953 to which both Barton and Hassel subscribed) by studying infrared spectra of cyclohexyl halides. However, no concerted thinking on the shape of cyclohexane and its derivatives was published until Hassel began his work in 1930. Initially Hassel used dipole measurements and x-ray diffraction techniques; the subjects of his research were mostly mono-, di-, and polysubstituted cyclohexyl halides. The tools were of limited applicability. Dipole measurements do not lend themselves to unique interpretation, and x-ray measurements are confined to the solid state. It was a big step forward, therefore, when in 1938 Hassel added electron diffraction to the arsenal of his experimental techniques. Electron diffraction put into evidence both forms of a monosubstituted cyclohexane (the equatorially and the axially substituted one), and Hassel soon perceived that the two forms exist in a very rapidly established equilibrium.

Hassel's early work appeared mainly in the German journals. There is an interesting postscript in one of his articles published in *Zeitschrift für physikalische Chemie* in January 1932: "This manuscript was sent to the Journal of the American Society on 26 September 1931; it was returned to us on 16 November with the referee's comments and a statement by the editor that the paper could not be published before February or March 1932; under the circumstances, we preferred to withdraw the paper and submit it to *Zeitschrift für physikalische Chemie.*" It is clear that refereeing delays occurred even 40 years ago, and it would appear that, in this particular instance, such a delay may have deprived the *Journal of the American Chemical Society* of a significant series of papers. In 1940, during World War II, German troops occupied Norway, and Hassel ceased to publish in German journals. As a result, his most significant work, which was done in the period 1938 to 1943, including his most important paper in *Tidsskrift for Kjemi og Bergvaesen og Metallurgi*, **3**, 32 (1943), appeared in Norwegian in relatively obscure journals unavailable in the allied countries during and immediately after the war. In the 1943 paper, Hassel clearly sets forth the principal tenets of the "static" stereochemistry of cyclohexane: (i) The molecule exists very largely in the chair (as distinct from the boat) form; (ii) when there is a substituent, a fast ring inversion occurs with a relatively low activation barrier; (iii) the substituent may thus occupy either the equatorial or the axial positions; (iv) the equatorial position is preferred (it was not clear, in 1943, by how much). These straightforward, but far from obvious points, almost completely explain (except for quantitative details) the chemistry of simple substituted cyclohexanes, and they have formed the basis of much research conducted in other laboratories between 1955 and 1965. As a result, cyclohexanoid compounds are among the best understood in organic chemistry today.

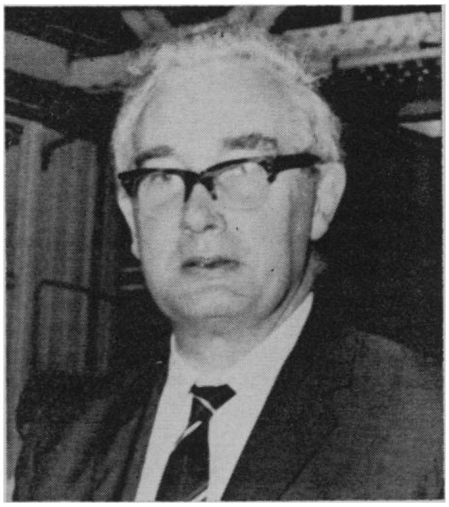
Because of the lack of availability and the lack of linguistic understanding of Hassel's most important papers,

Odd Hassel

His work was not really appreciated or widely applied for years after it was published. It was otherwise with the work of D. H. R. Barton. The effect of his pioneering paper in the field, published in 1950, was electrifying. It revolutionized organic chemistry and, later, chemistry as a whole. Any organic chemist active around 1950 still remembers the abrupt change in thinking, especially with respect to natural products, from an essentially two-dimensional and quite empirical view of the chemical reactivity of these substances in 1949 to an essentially three-dimensional and rational approach in 1951.

Barton was aware of Hassel's papers —at least those which had appeared after 1946—and has on several occasions expressed his indebtedness to Hassel's ideas. While Hassel, as a physical chemist, was mainly interested in molecular properties and molecular structure, Barton was an organic chemist whose main concern with natural products was tempered by an interest in mechanisms not yet common in the late 1940's. Among his early papers were some on the mechanism of thermal elimination reactions; he was interested in a priori computation of optical rotation, and his first conformationally oriented papers in 1948 dealt with calculations of intramolecular nonbonded interactions in ethane, cyclohexane, and the decahydronaphthalenes. Barton's salient writings were concerned mainly with the influence of conformation on chemical reactivity and on the position of chemical equilibria. In his 1950 paper he dealt with nearly all the important applications of conformational analysis: the greater stability of equatorial over axial substituents, their generally greater reactivity in reactions subject to steric hindrance, and the conformational requirements of the electrons involved in a change of bonding in a reaction (the so-called "stereoelectronic factor"). Pertinent illustrations are the conversion of axial to equatorial alcohols by equilibration, the greater reactivity of equatorial as compared to axial substituents in esterification and hydrolysis and the reverse order or reactivity in chromic acid oxidation of alcohols, and the tendency of ionic elimination reactions to involve *trans* diaxially placed substituents. Subsequent work by Barton and many others served to amplify the list of examples but not to modify the essential principles. Notable subsequent findings refer to the diaxial opening of steroidal epoxides (Furst-Plattner rule) and the anti-stereoelectronic feature of many important chemical and biochemical rearrangements and ring contractions—for example, the cyclization of squalene to lanosterol. In his second important paper on conformation (*J. Chem. Soc.*, **1953**, 1027) Barton expanded the application of conformational concepts to physical properties, such as adsorption affinity and infrared spectra; important later correlations in this area involve acidity, optical rotatory dispersion properties, and nuclear magnetic resonance spectra as a function of conformation.

Conformational ideas have revolutionized both the structure elucidation of natural products and their synthesis. In the former field they have led to a much better understanding of the course of many of the degradation procedures commonly used, thus greatly facilitating deductions regarding constitution and stereochemistry based on such degradations. In the latter, they have led to new principles in synthesis, such as the principle of conformational stereochemical control used by R. B. Woodward (Nobel laureate, 1965) in his total synthesis of reserpine. It is remarkable that this rapid development springs essentially from one or perhaps two papers by Barton—in fact, the total number of papers on conformational analysis from his laboratory probably does not exceed two dozen, including several comprehensive reviews. A factor which accelerated the dissemination of Barton's ideas was no doubt the fact that at a crucial time, in 1949–50, he served as visiting lecturer at one of the most active centers of chemistry in the United States; in his 1953 paper he expresses his heartfelt thanks "To (his) friends at Harvard in the fires of whose constructive criticism the ideas presented here were first tempered."



Derek H. R. Barton

Hassel ceased active work in the field of conformational analysis in 1955, Barton in 1960. Under the impetus they provided, however, the field has continued to grow in scope and importance, not only along the lines of a more quantitative understanding of alicyclic and heterocyclic rings of a variety of sizes, but also in the area of the conformation of acyclic compounds both small (substituted ethanes) and large (polymers and bipolymers, including proteins). Of course, the latter areas have their historical origin in the work of Mizushima, Kenneth Pitzer, Pauling, and others; however, they have received important cross-fertilization from the ideas of the 1969 Nobel laureates in chemistry.

Odd Hassel was born in Oslo, Norway, in 1897. He received the Cand. Real degree from the University of Oslo in 1920 and the D. Phil. degree from the University of Berlin in 1924. He joined the faculty of the University of Oslo in 1925, and, from 1934 to 1964, served as director of the Physical Chemistry Department there. Although now retired, he is still active in research; since the middle of the 1950's his papers have been concerned mainly with the structure of organic complexes of the halogens and similar compounds. His career was interrupted from 1943 to 1945 when German forces closed the University of Oslo and imprisoned Hassel. Hassel's list of honors includes the Order of St. Olav, the Guinerus medal, the Guldberg-Waage medal, and honorary degrees from the Universities of Copenhagen (1950) and Stockholm (1960).

Derek H. R. Barton was born in Gravesend, England, in 1918. He attended Gilligham Technical College and proceeded to Imperial College which conferred the B.Sc. degree on him in 1940 and the Ph.D. degree in 1942; he also holds a D.Sc. degree from the parent University of London (1940). From 1942 to 1945 he was engaged in war work; from 1945 to 1949 he was at Imperial College as assistant lecturer and later as research fellow. He served as visiting lecturer at Harvard University, 1949–50, and joined the faculty of Birkbeck College, University of London, as reader in 1950, becoming professor of organic chemistry there in 1953. From 1955 to 1957 he was Regius Professor of Chemistry at the University of Glasgow (Scotland) and since 1957 he has been professor of organic chemistry at Imperial College. His numerous honors include the Hoffman prize (Imperial College, 1940), Harrison Memorial prize (Chemical Society of London, 1948), Corday-Morgan medal (Chemical Society, 1951), Fritzsche award (American Chemical Society, 1959), Roger Adams award (American Chemical Society, 1959), and Davy medal (Royal Society, 1961). He holds honorary degrees from the universities of Montpellier, France (1962) and Dublin, Ireland (1964) and is a fellow of the Royal Society and the Royal Society of Edinburgh and a foreign member of the American Academy of Arts and Sciences. Barton has served in numerous invited lectureships, including the Tilden lectureship of the Chemical Society (1952), the Arthur D. Little visiting lectureship at the Massachusetts Institute of Technology (1958), the Karl Folkers lectureship, Universities of Illinois and Wisconsin (1959), and the Peter C. Reilly lectureship, University of Notre Dame (1960).

Both Hassel and Barton are prolific researchers; Hassel has published well over 100 papers and Barton over 300. Although Barton has not been active in conformational analysis since 1960, he still publishes extensively on natural products; his recent interests have been mostly in photochemistry and in biosynthesis. He is one of the directors of the Research Institute for Medicine and Chemistry, a nonprofit research laboratory located in Cambridge, Massachusetts, and, in this connection, visits the United States at least twice every year. It was in this institute that the well-known "Barton reaction" (photochemical rearrangement of a nitrite with a proximal methyl group, yielding an alcohol oxime), which has led to a facile synthesis of aldosterone, was discovered in 1960.

Both Hassel and Barton are basically self-contained individuals. Hassel is quite retiring, rarely ever attends international meetings, and is known personally to only a few workers in the field of conformational analysis. It is reported in the press that he has not yet decided whether to make the short trip to Stockholm to receive the Nobel prize in person, as he shuns public appearances. Barton, on the other hand, has always been very cognizant of the need and responsibility of the scientist to expose his ideas; he has written several lucid and comprehensive reviews of his subject and, despite his demanding obligations as a very active scientist, a university lecturer, and an administrator, he has shown a remarkable willingness to accept lecturing engagements elsewhere and to stimulate others in the comprehension and application of an area of chemistry which has become one of the pillars of the science today.

ERNEST L. ELIEL
Department of Chemistry,
University of Notre Dame,
Notre Dame, Indiana

3. Physics

To the surprise of no one in the international physics community, the 1969 Nobel prize in physics was awarded to Murray Gell-Mann, Millikan Professor of Physics at the California Institute of Technology. Standard physics cocktail party conversation for the past 6 years in late October was always, "I wonder if Murray will get it this year."

The citation "for his contributions and discoveries concerning the classification of elementary particles and their interactions" cannot, of course, communicate anything like Gell-Mann's influence on elementary particle physics. What so distinguishes Gell-Mann's contributions is the fact that he has been involved in a major way in almost every important theoretical advance in elementary particle physics for the past 15 years. This is a very popular and competitive field, and in many cases other people have done the same things independently and simultaneously. But Gell-Mann's domination of the subject is truly amazing. It is perhaps best illustrated by the following story. The organizers of the 1966 International Conference on High Energy Physics, held at Berkeley, planned to have a series of talks reviewing the developments in the various parts of elementary particle physics during the 2-year interval between conferences and highlighting what would be the things likely to be important at the conference. The reason for this was that the field had grown so rapidly that experts in the weak decays of particles, say, could not know what was going on in the reactions between π-mesons and protons at energies around 20 billion electron volts (Gev). After much wrangling over which five or six people should do this important job, someone made the inspired suggestion that Gell-Mann do the whole thing. In a 1½-hour talk he covered the whole field, which he knew completely, having worked on almost all aspects of it.

Gell-Mann's physics is characterized by taste, deep physical intuition firmly based on an intimate knowledge of experimental facts and fundamental theoretical ideas, and great technical power. He enthusiastically accepts the ideas of others, rejects dogmas, and is concerned solely with trying to understand nature.

Murray Gell-Mann was born in New York City on 15 September 1929. He was introduced to languages and mathematics by his father and was awakened to the world of natural history by his older brother Benedict—an interest which has played an important role in his life. He entered Yale at the age of 15 to study mathematics, but fortunately discovered physics and went to M.I.T. to do graduate work, in 1948. After receiving his degree in 1950 and spending a year at the Institute for Advanced Study, he joined the faculty of the University of Chicago, where he rose to the rank of associate professor before leaving in 1954. After a year at Columbia and the Institute, he went to Caltech, where, except for occasional leaves of absence, he has been ever since.

To review all of Gell-Mann's contributions would take too much space, and would probably tell many readers more than they want to know about elementary particle physics. Consequently only a few of the more spectacular ones are described here. The first of these was made in 1953.

There had been discovered in cosmic ray events some very strange particles (subsequently produced by high energy accelerators), some with masses about 1000 times the electron mass [it is customary to give these things in the energy equivalent to the mass, in this case 500 million electron volts (Mev)], which decayed into two or three π-mesons (mass 140 Mev), and another group which decayed into neutrons or protons (mass 938 Mev) and π-mesons. These particles are shown in Table 1. Those in the first group are called collectively mesons; those in the second, baryons. The outstanding puzzle about these particles, discovered in the late 1940's and early 50's, was that, although they were copiously produced and decayed into particles which were known to interact strongly, they lived amazingly long, 10^{-10} second, as compared to the "natural" strong interaction time scale of 10^{-23} second. The resolution of this particular puzzle was provided independently by A. Pais and Y. Nambu, who suggested that the strange particles were always produced in pairs and could then interact strongly, but that in decaying, which they do singly, they interact very weakly. This did not explain, however, why in a collision between a neutron and a proton one did not produce a Λ^0 and a Σ^+, say. It was Gell-Mann's profound contribution to recognize the relation between isotopic spin symmetry (used to classify particles into groups or multiplets, as they are called, which all have about the same mass but have different charges, and which can transform into each other in strong interactions) and the two faces of strange particle behavior. The so-called isotopic multiplets are shown in Table 1. Notice that the center of charge of the doublet neutron and proton is at $+\frac{1}{2}$, whereas that of the Λ^0 and the triplet of Σ's is at 0, while that of the doublet of Ξ is at $-\frac{1}{2}$. A new quantity called the strangeness quantum number S, equal to twice the amount of the center of charge displacement from that of the neutron-proton doublet, was defined by Gell-Mann. Thus $S = -1$ for Λ^0 and Σ and $S = -2$ for Ξ. A similar classification of the mesons is made: the π-meson isotopic triplet has $S = 0$, while the doublet K^0, K^+ has $S = +1$, while their antiparticles $\overline{K}^0$ and K^- have $S = -1$. From the known isotopic spin symmetry in strong interactions, one can show that S is conserved in such reactions. This means the sum of particle strangenesses before and after a reaction must be the same. Thus $\pi^- + p \rightarrow \Lambda^0 + K^0$ is allowed, whereas $n + p \rightarrow \Lambda^0 + \Sigma^+$ should not occur or, rather, should occur at a rate 10^{-13} times that for an "allowed" reaction. Thus a decay $\Lambda^0 \rightarrow p + \pi^-$, since $S = -1$ for Λ^0 and $S = 0$ for proton and π^- meson violates the conservation law and thus decays very weakly. This beatiful and elegant idea was simultaneously and independently put forward by Nakans and Nishijima in Japan.

Murray Gell-Mann

Table 1. The stable or very long-lived particles known in 1953. The mesons $K^\pm$, K^0, $\overline{K}^0$ and the baryons Λ^0, $\Sigma^\pm$, Σ^0, Ξ^0, Ξ^-, are the strange particles discovered in cosmic radiation and in reactions initiated by high energy particles from accelerators.

Charge			Mass (Mev)
−1	0	+1	
	Baryons		
Ξ^-	Ξ^0		1315
Σ^-	Σ^0	Σ^+	1195
	Λ^0		1115
	n	p	938
	Mesons		
	K^0	K^+	495
K^-	$\overline{K}^0$		
π^-	π^0	π^+	140

The next flamboyant contribution by Gell-Mann appeared early in 1961. (One should not get the idea that he was loafing during the intervening 8 years; for example, he did very important work on the theory of weak interactions, in collaboration with Feynman in 1958.) This was the idea of grouping the isotopic multiplets shown in Table 1 into supermultiplets according to a particular mathematic structure called the group SU(3). Suffice it to say that there exists a representation of this group involving eight elements, just the number of baryons in Table 1, and it was natural to include the mesons in a similar classification, leading to the prediction of an eighth meson (called η^0 and subsequently discovered). If the real world were actually as symmetric as the theory, all these octets of particles would have the same mass, which is of course not true. By making assumptions about how the symmetry is broken in nature, one can predict relations among the various masses. This fact opened the door for a really big prediction within the framework of Gell-Mann's theory. It had been known for some time that, in collisions between π-mesons and protons, there was produced what is called a resonant state of the nucleon of mass 1238 Mev. It was found that the strange particles

Table 2. The pattern of excited states of the baryons together with the spectacular Ω. The letter Y, called hypercharge, is, in this case, the strangeness S plus one; I refers to the isotopic spin.

	Ω^-	Ξ_{10}	Σ_{10}	Δ
Mass (Mev)	1679	1532	1385	1238
Y	−2	−1	0	1
I	0	1/2	1	3/2
Charge				
−1	✓	✓	✓	✓
0		✓	✓	✓
+1			✓	✓
+2				✓

showed similar resonances. Such states are shown in Table 2. In 1962, when only the Δ (1238) and Σ_{10} (1385) were known, Gell-Mann predicted the existence of the Ξ_{10} (1532) and the Ω^{-} (1679). When these particles were found, and, in particular, when the Ω^{-} was found, in 1964, there was no question about the importance of this theory. This theory is incidentally also the one which led Gell-Mann, following a remark by Robert Serber (and, independently, George Zweig), to speculate on the possible existence of entities called by him "quarks," which might be thought of as fundamental building blocks of the particles themselves. The basic idea of particle classification according to the group SU(3) was published virtually simultaneously by Yuval Ne'eman, who had been working at Imperial College with Abdus Salam.

One could go on and talk about Gell-Mann's very important work called current algebra, first proposed by him in 1961 but actually published in 1964. This is, however, too technical. Instead, let me conclude with a few remarks about Gell-Mann's extracurricular interests. He is fluent in several languages, knows individual words in very many (although he is known, experimentally, to be quite deficient in Erse), has a deep knowledge of linguistics, and is insistent about proper pronunciation of foreign words, such as saying always "Fe*r-r-r*-mi" instead of simply "Fermi." He has been a life-long bird watcher and hiker-camper and has recently become seriously involved with problems of the environment. He helped organize a summer study in 1969 sponsored by the Environmental Studies Board of the National Academy of Sciences. He is currently a member of the President's Science Advisory Committee.

The Nobel Committtee has done itself proud.

M. L. GOLDBERGER
Princeton University,
Princeton, New Jersey

The Population Crisis: Rising Concern at Home

Mention of the impending world population crisis usually has evoked images of undernourished, famine-threatened villagers of underdeveloped countries such as India, Egypt, and Haiti. Now, however, population growth is coming to be viewed as a serious domestic as well as a world problem. With only 204 million inhabitants in a territory of continental size, the United States is, by comparison with many nations, thinly populated; but the concentration of people in the larger urban areas, especially those of the Northeast, California, and the Great Lakes states, is making many Americans uneasy about the chamber of commerce belief that bigger means better.

Increasingly, it becomes evident that bigger is likely to mean more urban sprawl, more air and water pollution, more traffic congestion and teeming ghettos, and more overcrowding in schools and recreation areas. And, if 200 million Americans are too many, what about 300 million, the number forecast for the year 2000, or 400 million, the population forecast by some for 2040?

The fact that rapid population growth inevitably aggravates (and is often the major cause of) a variety of environmental and social problems promises to hasten the latest transformation of the birth control issue which has undergone a remarkable evolution since the turn of the century. That issue was first taken up by the feminists. Later, many physicians also became interested because they viewed the legal prohibitions of some states against the prescribing of contraceptive methods as an infringement upon their professional rights and responsibilities.

Then, within the last decade or so, many people (and an increasing number of politicians) began to proclaim, as basic to human dignity, the right to decide whether to bear a child or not —and, in so doing, they transformed birth control into something politically respectable. Now, finally, the issue becomes one of broad concern, of interest to all who see the population expanding—currently at a rate of about 2 million a year—without regard to the future availability of resources or to the effect on the quality of life.

This year members of Congress have, by the score, been proposing or cosponsoring legislation intended to increase the effectiveness of family planning programs or to establish new government agencies which would develop policies aimed at keeping population and resources in balance. For example, in May, Senator Joseph Tydings (D–Md.) introduced a bill to establish in the Department of Health, Education, and Welfare a national center for population and family planning which would take over direction of the programs of birth control research, training, and services which are now scattered throughout HEW. At last count, 24 senators and 64 representatives were cosponsoring the Tydings bill and its companion measure in the House. On 23 October, HEW announced that it was setting up a National Center for Family Planning, thus responding to the congressional pressure (though reorganization planning had been under way for some time).

Other legislation, introduced by Representative Emilio Q. Daddario (D–Conn.), a Catholic, and Representative Charles A. Mosher (R–Ohio), would redesignate (and reorient) the Department of the Interior as the Department of Resources, Environment, and Population. This measure is being supported, as a vehicle for discussion if nothing else, by the Republican Task Force on Earth Resources and Population, a group set up last April by House Republicans under Representative George Bush (R–Texas) as chairman. Interest in this and other population measures not only cuts across party lines but, within each party's ranks, reaches to both the conservative and liberal ends of the spectrum.

In July President Nixon sent to Congress his message on population problems—the first presidential message ever devoted entirely to the population issue. Although the message was concerned partly with programs of assistance to birth control efforts in the developing nations, it dwelled at length on the matter of the mounting population pressures at home. The President