letters

A portrait of Pauli

May I contribute to the growing collection of stories about Wolfgang Pauli? In 1936 the late mathematician Stanislaw Ulam and I were visiting members of the Institute for Advanced Study in Princeton. We felt it was time to reciprocate in some way the hospitality of many of our married colleagues and friends from the institute. Inasmuch as Stan had a rather small room in town we arranged an after-dinner party in my rooms at the Graduate College. (At that time some of the surplus rooms in the college were occupied by members of the institute.) To entertain our guests Stan and I proposed various games, one of which consisted of drawing on a pad of paper one's own caricature. The response of the by then quite "relaxed" group was enthusiastic, except for Pauli, who refused to draw. Finally, under a barrage of questions, he started pacing up and down and, shaking his head in the well-known way, said, "I cannot do this, I am my own caricature."

Franka Pauli, who is mentioned in W. B. Gleason's letter (August, page 11), was there too and again was a center of considerable attention. To the dismay of the night watchman the party continued well past curfew time and as a result the next day I was called on the carpet by the master of the college. Fortunately the star-studded guest list acted as a good excuse.

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Crystals and Nobels

The awarding of the 1985 Nobel Prize in Chemistry to two more members of the American Crystallographic Association, Herbert A. Hauptman and Jerome Karle (PHYSICS TODAY, December 1985, page 20), brings the number of Nobel Prize winners associated with x rays and crystals to 21. Since the total world population of crystallographers,[1] most of whom use x rays, is less than 10 000, the young x-ray crystallographer would appear to have better odds of winning a Nobel Prize than a worker in any other field of endeavor. One may ask why this is so.

Thirteen years after the discovery of x rays by Wilhelm Röntgen (Nobel Prize in Physics, 1901), Max von Laue (Physics, 1914) discovered x-ray diffraction. But it was William and Lawrence Bragg (Physics, 1915), both of whom were educated as mathematicians,[2] who exploited those findings to determine the atomic structure of crystals. These discoveries, together with the development of x-ray physics by Charles G. Barkla (Physics, 1917), Karl M. G. Siegbahn (Physics, 1924) and Arthur H. Compton (Physics, 1927), removed crystallography from its 300-year-old association with mineralogy and moved it to the domain of physics. The physics laboratories of the Braggs, first in Leeds, then in Cambridge and London, were the meccas for disciples of the new science of x-ray crystallography.

Two other radiations, electron and neutron, that also can have wavelengths suitable for atomic diffraction joined the x rays, and diffraction became the primary source of precise quantitative information about the three-dimensional structure of matter in gases, liquids and amorphous solids, as well as crystals. Because it is this three-dimensional atomic structure that determines the physical, chemical and biological properties of substances, use of these diffraction methods became a common interest for a broad spectrum of sciences. This interdisciplinary theme started with Peter J. W. Debye (Chemistry, 1936) and runs through the history of the later Nobel laureates. Linus Pauling (Chemistry, 1954) used his experience in crystallography extensively in writing *The Nature of the Chemical Bond.* Giulio Natta (Chemistry, 1963) applied crystallography to his polymer research. Francis H. C. Crick, who had been a physicist, collaborated with James D. Watson, a biologist, in interpreting the x-ray diffraction patterns of physicists Maurice H. F. Wilkins and Rosalind Franklin, and so discovered the double helix (Physiology and Medicine, 1962) with a little help from Jerry Donohue, a chemist.

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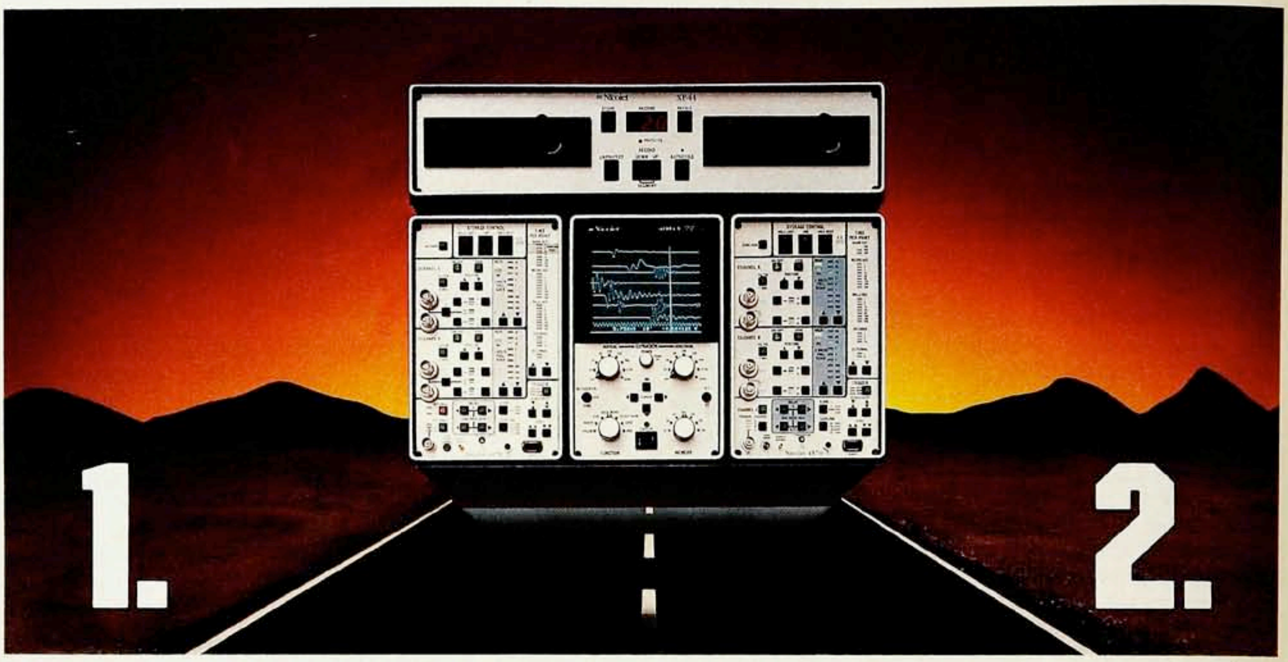

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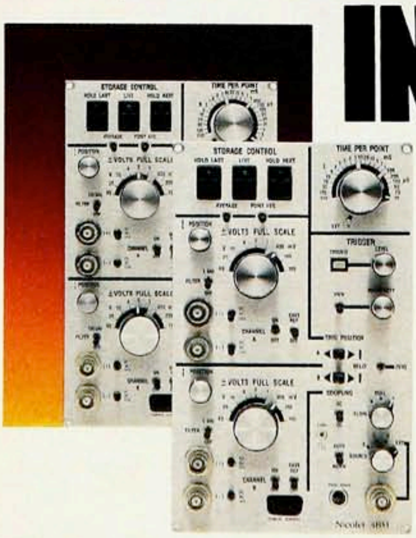

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Once the simpler inorganic crystal structures had been determined, the methodology of crystal structure analysis became very difficult, especially when applied to organic molecules. This was because of the phase problem. While this gave the research considerable intellectual appeal—like playing chess against Nature—it made it very time consuming and often tedious. Nevertheless some scientists with special combinations of curiosity, insight and determination persisted, such as Max F. Perutz (Chemistry, 1962), Dorthy M. C. Hodgkin (Chemistry, 1964), Odd Hassel (Chemistry, 1969), William N. Lipscomb Jr (Chemistry, 1976) and Monteith Robertson. Although the last named was not awarded a Nobel Prize, he was elected president of the Chemical Society (UK) in recognition of his crystallographic contributions to chemistry. Assisted by the rapid development of computer technology, but using methods developed for small molecules by Arthur L. Patterson (a physicist) and Robertson (a chemist) in the 1930s, Perutz and John C. Kendrew (Chemistry, 1962) demonstrated the use of x-ray crystallography to determine the atomic structures of very large molecules, namely proteins. Physicist Aaron Klug (Chemistry, 1982) extended this work to methods for the structure analysis of even larger molecules, the viruses.

With the recognition of the importance of molecular shape, or conformation, by Hassel and Derek H. R. Barton (Chemistry, 1969), x-ray crystallography began having a tremendous impact on chemistry. Crystallography was able to play such a major role in chemistry because of the invention of a mathematical method, based on probability theory, for solving the phase problem. It was for this invention that Hauptman, a mathematician, and Karle, a chemist, were awarded the Nobel Prize in Chemistry.

Interdisciplinary transfer or collaboration between the major disciplines in science is a theme that runs through these discoveries. Yet the increasing sophistication of the sciences has led to a segregation in university education that drops the curtain between them at increasingly earlier stages. It is rare that a graduate physicist can, or wishes to, understand the language of even an undergraduate chemistry course. A solid-state physicist can be surprised to learn that proteins and viruses can be crystals. Similarly the mathematical logic of physics undergraduate courses is a mystery to most biochemistry and biology students.

Crystallography is fortunate in that through the congresses of its International Union, the 14th of which will meet next year in Perth, Australia, and its publications, it serves as a meeting place for the sciences. At these congresses, the physical, chemical and biological properties of substances are related to their atomic structures by discussions among chemists, crystallographers, mathematicians, mineralogists, solid-state physicists and materials scientists.

Perhaps that is part of the answer to the question.

References

1. *World Directory of Crystallographers*, 7th ed., Reidel, Boston (1986).
2. C. M. Caroe, *William Henry Bragg, 1862–1942*, Cambridge U. P., London (1978).

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The 'social purpose' of SSC

After reading the barrage of letters (April, page 11) responding to Leon Lederman's reply to Rustum Roy's letter (September 1985, page 9), I feel compelled to add my views on the need for SSC. The dominant theme in Roy's view is that high-energy physics is not basic science. In his view, basic science is "that which is closest to human needs and which holds out hopes for the greatest effect on the greatest number of the nation's citizenry." This broad statement may be applied to agricultural engineering as well as to religion. Lederman did not address this matter directly in his response. I hope to do so here.

First, as a graduate student in high-energy physics, I am insulted to be told that I am drawn to the field because it is the "most glamorous, most high-powered, most prestigious, most arcane, [and] the smallest." My reason is the one that draws so many people to science, and physics in particular, but one that few people articulate: How did we, and the rest of the universe, get here? What makes us, and the rest of the universe, tick?

Such questions are basic to human nature, and are the basis of both religion and science. Recent discoveries (the W particles and the Z), and theoretical concepts such as QCD and supersymmetry, to name only a few, lead me to believe that such general questions may be answered by the human race in the future. The fields that currently ask such questions are high-energy physics, cosmology and astrophysics. But, to put words into Roy's mouth, what would be the social purpose of this knowledge? I ask him, what was the social benefit of the