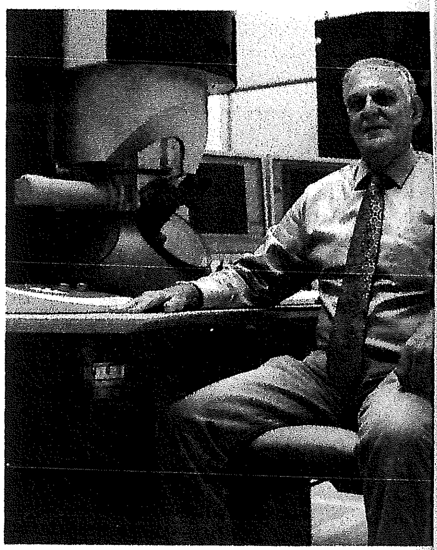
PRIZE FOR CHEMISTRY

The Nobel Prize for Chemistry in 2011 went to Daniel Shechtman, of the Technion-Israel Institute of Technology, Haifa, for discovering a new form of matter called "quasicrystals." The essence of the quasicrystal is the way it differs from a crystal. Crystals have lattices in which the local structure repeats throughout the system. For example, in table salt each sodium atom is surrounded by six chlorine atoms, and likewise each chlorine is surrounded by six sodiums, in a repeating cubic arrangement. In a quasicrystal the immediate neighbourhood of each atom has a regular structure, but that structure does not repeat in a periodic way.

Shechtman was born on Jan. 24, 1941, in Tel Aviv. He received a bachelor's degree in mechanical engineering (1966) and a master's (1968) and a doctoral degree (1972) in materials engineering from Technion. From 1972 to 1975 he was a postdoctoral associate at the Aerospace Research Laboratories at Wright-Patterson Air Force Base, Dayton, Ohio. From 1975 he held various positions at Technion, finally becoming a professor in 1984. He was a visiting professor at Johns Hopkins University, Baltimore, Md. (1981–97), and at the University of Maryland (1997–2004). From 2004 he also served as a professor of materials science and engineering at Iowa State University.

The possibility of such aperiodic structures had been conjectured in the 1960s for two dimensions. Mathematicians wondered if a surface could be covered by tiles, with no vacant spaces between them, in a way that had no periodic repetitions. (Examples of such tilings actually existed in medieval Islamic floors, such as in the Alhambra in Spain, but these were unknown to mathematicians and crystallographers.) The first pattern to accomplish this was completed in 1966 and used over 20,000 different tiles, but by the mid-1970s this had been reduced first to 40 and then, by Roger Penrose, to only 2. Robert Ammann extended the concept of such aperiodic structures to three dimensions. However, at that time aperiodic materials were only an idea.

Daniel Shechtman



Oliver Weiken—EPA/Landov

While Shechtman was a guest researcher in 1982 at the National Bureau of Standards (NBS; now the National Institute of Science and Technology) in Gaithersburg, Md., he began studying alloys of aluminum with manganese or iron. He used the standard structure-probing tool of scattering electrons from the solids; the scattered electrons form regular patterns of localized spots, whose arrangement on the detector reveals the crystal's structure. The patterns from Shechtman's alloys, however, did not correspond to any known crystal lattice structure. Those lattice structures had been well understood since 1848, when they were cataloged by August Bravais—and hence became known as Bravais lattices. Bravais lattices yielded concentric circles made of four or six spots. The patterns produced in Shechtman's diffraction experiments had an unusual 10 spots on a circle, yet his materials must have had a regular pattern because a disordered material, such as a glass or a liquid, would have produced only diffuse rings, not sharp spots, in its scattering pattern. How could a solid yield such a pattern, one with regularity but not a crystal? Shechtman was able to show, by rotating his samples, that they had fivefold symmetry, which is inconsistent with any periodic lattice.

Shechtman's findings puzzled him and many others. Some disbelievers scoffed, and his supervisor asked him to leave his research group. Back at Technion he and colleague Ilan Blech prepared a paper interpreting the pattern in terms of atomic structure. The paper was rejected upon submission. Shechtman then turned to the senior scientist who had brought him to NBS, John Cahn, who in turn engaged French crystallographer Denis Gratias. The four wrote a new paper in 1984 showing that a solid could not only have long-range orientational order but also lack the translational symmetry that characterizes a crystal. The structures Shechtman had found exhibited icosahedral symmetry. The icosahedron had 20 identical pentagonal faces arranged so that an observer looking directly at one of those faces would be able to rotate the object one-fifth of the way through a circle and not be able to distinguish it from its original state. A few weeks after Shechtman's paper appeared, Dov Levine and Paul Steinhardt interpreted the result by relating it to a three-dimensional model developed by Alan Mackay; they introduced the term *quasicrystals*. Subsequent research revealed about 100 intermetallic quasicrystals.

(R. STEPHEN BERRY)