some of the icy surrounding material into distant orbits, forming the Oort cloud.

If so, many comets undoubtedly exist outside the cloud. Dynamical studies by several groups, including Martin Duncan of the University of Toronto and colleagues, suggest that most of the comets broke free from the sun's hold and sailed into interstellar space. This process is still occurring (at a very slow rate) today. Our solar system alone may have shed 100 trillion comets. If ours is typical, the Milky Way should contain hundreds of billions of comets per cubic light-year.

These interstellar comets fascinate S. Alan Stern, an astronomer at the University of Colorado at Boulder, who calls them "the smoking gun of planetary formation." If one of them were to approach the sun, it could easily be identified because it would follow a hyperbolic path rather than the parabolic paths of comets from the Oort cloud.

The density of interstellar comets should reflect the fraction of stars that have planetary systems to eject the comets. So far, however, not a single comet has been seen to follow a hyperbolic path. Stern hopes a multiyear, dedicated search for faint hyperbolic comets will settle the question of whether planetary systems are common features or a lucky fluke. Paul R. Weissman of the Jet Propulsion Laboratory is concerned that "a deliberate search is beyond anything now practical." Finding a hyperbolic comet will just take patience—perhaps 50 to 100 years of waiting, he thinks.

A faster way to locate interstellar comets might be to search directly for Oort clouds around other stars. Comets that approach their star will evaporate and shed dust that would emit infrared radiation. The National Aeronautics and Space Administration's *Infrared Astronomical Satellite* failed to find such emission; the upcoming *Space Infrared Telescope Facility* might be sufficiently sensitive to do so.

In *Nature*, Stern's group suggests that red giant stars might be bright enough to heat their Oort clouds to visibility. The star's energy would cause water molecules and hydroxyl radicals to emit radiation. This signal could be detectable because stars are too hot to radiate at these wavelengths.

Astronomers are understandably excited by the prospect of finding comets from other stellar systems. Stern muses that the only other way to determine the prevalence of planetary systems throughout the galaxy is to "talk to an extraterrestrial visitor"—of the noncometary kind. —*Corey S. Powell*

PROFILE: Modest Maverick

Hoffmann's world of chemistry, poetry and pedagogy

Nobel laureate Roald Hoffmann caresses a model of a molecule whose geometry he calls "seductive and beautiful." To me, it's just yellow triangular panels with green spheres at the corners. He traces his finger from a sphere—an atom—along the edge of a panel—a molecular bond. Then I notice that the panels form a series of tetrahedrons stacked one on top of the other. Touching three atoms at a time, Hoffmann twists his hand around the model, revealing a triple helix. I begin to decipher the intricate structure of this "tetrahelix." But is it art?

Chemists certainly commend the beauty of Hoffmann's work. He was awarded the 1981 Nobel prize in chemistry and the 1990 Priestley Medal, the American Chemical Society's highest honor. Now Hoffmann would like all scientists and humanists to appreciate the aesthetics of chemists' work. The tetrahelix, he explains, is beautiful not just because of its shape but also because of its novelty, its dynamics, its utility, its richness.

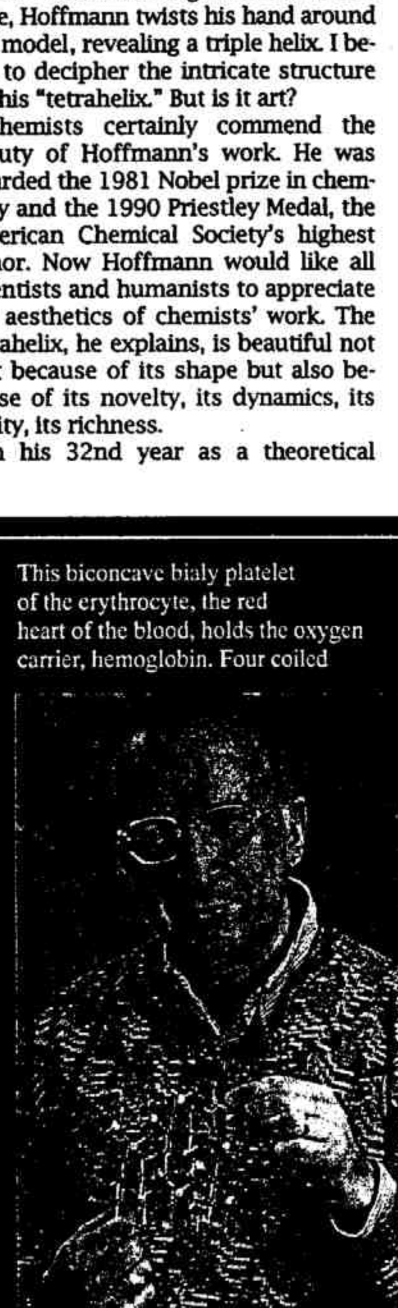
In his 32nd year as a theoretical chemist, Hoffmann now devotes much of his time to communicating the beauty of molecules. As a professor at Cornell University, he awakens first-year students to the fundamentals of chemistry. As a poet and writer, he exposes the connections that unite chemistry, literature and art. As a television-show host, he will introduce viewers to *The World of Chemistry*—a series of 26 half-hour programs scheduled to air on public television in September.

It is a wonder that Hoffmann can find any beauty in his life after its ugly beginnings. In June, 1941, a month before his fourth birthday, German troops marched into his hometown of Złoczów, Poland (now Zolochev in Soviet Ukraine). Nazi officers forced him, his father, Hillel Safran, and his mother, Clara, to move to a Jewish ghetto. A few months later they were deported to a labor camp called Lackie.

In January, 1943, Safran arranged to smuggle his wife and Roald out of the camp. They were received by a Ukrainian teacher who hid them in the attic of a schoolhouse. In this dark, cramped room, Clara began to teach her son geography and reading.

Later, in June, his father made plans to escape from Lackie with several other prisoners. The Nazis discovered his

This biconcave bialy platelet
of the erythrocyte, the red
heart of the blood, holds the oxygen
carrier, hemoglobin. Four coiled



Roald Hoffmann

polypeptide chains, four subunits
changing pairwise twice in the fetus
to let it soak up placental O_2
steadily. Each chain a globular

protein, juxtaposed twining
of helical segments, predestined
kinks, sequences of amino acids
alike in sperm whale and horse.

a meander of bonds around
the flat disc that colors all...heme,
the active site, the oxygen binding
site, a porphyrin, iron. Oxygen,

enflamer, winds to a pocket
molded by protein, binds iron, moves
it in consummation, chains
tethering heme tense—a far

subunit feels the first heme's bond
quiver, the chains pull, O_2 binds
easier. Cooperativity, an allosteric
protein. In 1937

not long before the war.
Felix Haurowitz watched crystals
of deoxyhemoglobin
shatter on oxygenation.

from "Jerry-Built Forever,"
Gaps and Verges

plot and executed him. Hoffmann later wrote in a poem, "...I was five/when the news came to us in the Ukrainian's attic,/and I cried, because my mother cried. That's when/my father became a hero.... The war ended,/80 of 12,000 Jews in our town survived."

After their liberation in June, 1944, Roald and his mother journeyed to Kraków, Poland. There Clara met Paul Hoffmann, whose wife had died in the Holocaust. A year later they were married. Hoffmann remembers his stepfather as a "kind and gentle" man. The Hoffmann family traveled through Czechoslovakia to Austria to West Germany and finally emigrated to the U.S. in 1949.

Hoffmann was introduced to chemistry at an early age through the biographies of Marie Curie and George Washington Carver. "I showed neither precocity nor early interest in chemistry," he commented during a recent interview. In the fall of 1955 Hoffmann entered Columbia University to prepare for a career in medicine. "My mother wanted me to become a doctor; maybe by now she's forgiven me for becoming a chemist," he said with a smile.

At Columbia, Hoffmann studied everything from mathematics to French to chemistry, taking six or seven classes each semester. He found art history most intriguing and nearly abandoned the laboratory in favor of the gallery. He completed his course work in only three years and graduated summa cum laude in chemistry.

Hoffmann's affinity for chemistry, however, mainly developed during the summers of his college career, when he studied the chemistry of cement and hydrocarbons at the National Bureau of Standards. It was this experience that motivated him to attend graduate school at Harvard University. For his doctoral thesis, working under Nobel laureate William N. Lipscomb, Jr., he predicted the structure of polyhedral hydrocarbons and boranes.

After receiving a Ph.D. in chemical physics in 1962, Hoffmann accepted a three-year fellowship at Harvard. It was during this period that he began his two most important collaborations: the first with Harvard professor Robert B. Woodward investigating the theory of organic chemistry; the second with his wife, Eva, raising two children, Hillel Jan and Ingrid Helena.

Woodward and Hoffmann formulated a general rule, which has been regarded as the most important conceptual advance in theoretical organic chemistry. As molecules combine with one another, they sweep through transition states. The reaction will proceed with ease if the energy of the transition states is low and with difficulty if it is high. The Woodward-Hoffmann rule is a procedure for relating the energy of the transition states to the number of electrons involved in the reaction and their motions.

During his collaboration with Woodward, Hoffmann developed and refined a distinctive research style. "I don't start with big tasks or the great questions of chemistry," he remarked. "I do many small problems inspired by experimental work. I try to explain the shape of a molecule or some reaction. Everything in the world is connected to everything else. I know I will begin to see connections."

Hoffmann has successfully applied his methods to organic, inorganic and solid-state chemistry. He has devoted roughly 10 years of his life to each, but he confesses that his decisions to switch were not conscious or sudden. "I have always done the next interesting thing."

At times when Hoffmann has just entered a new field, his colleagues have criticized his work for being too simplistic. But propelled by his early successes, Hoffmann has managed to excel. In inorganic chemistry, he developed a technique to predict the structure and reactions of organometallic compounds. In solid-state chemistry, he translated the physicist's concept of densities of electron states into the chemist's idea of molecular orbitals. Indeed, Hoffmann is the only person in the history of the American Chemical Society to be honored for work in both organic and inorganic chemistry.

Hoffmann was only 44 when he shared the Nobel prize with physicist Kenichi Fukui of Kyoto University. Hoffmann received the prize in part for his contribution to the Woodward-Hoffmann rule. Had Woodward not died two years before the Nobel committee's announcement, Hoffmann believes, Woodward would have also been awarded the prize.

In many ways, Hoffmann's style of chemistry pervades his teaching. Even in introductory courses, he feels it is important to communicate what modern chemists find exciting. He prefers to begin a lecture with a discussion of a paper from the current chemical literature. He then highlights the connections between the paper and the curriculum. Nearly every year since starting at Cornell in 1965, he has taught introductory chemistry, which was attended this spring by 740 students.

Hoffmann believes that teaching complements his research efforts. "The desire to teach others, enhanced by being *obliged* to teach others, leads to greater creativity in research," he wrote in a column for the *Boston Globe* last November.

Out of a desire to express the beauty of chemistry and his own emotions, Hoffmann at the age of 40 began to write poetry. He was inspired by Mark Van Doren, a professor of poetry at Columbia, and Pulitzer prize-winning poet Wallace Stevens. "I should have taken a course, but I thought I was too old." Today his source of "valuable criticism and support" comes from a group of Cornell poets, including A. ("Archie") R. Ammons.

Hoffmann recently finished his second volume of poetry, *Gaps and Verges*, published by the University of Central Florida Press. Among his topics are his childhood experiences, romance, natural beauty and, of course, chemistry. Peter Harris wrote of his work in the *Virginia Quarterly Review*, "At times, Hoffmann's treatment of the scientific seems prosy.... But, in general, his poetry is distinguished by the appreciative ease [with] which it moves between scientific and nonscientific understanding."

Branching out from his poetry projects, Hoffmann has written several articles on science policy and many essays for the magazine *American Scientist*. Recently he teamed up with artist Vivian Torrence to produce a book entitled *Chemistry Imagined*. Torrence is creating some 25 collages on chemical themes. To accompany these images, Hoffmann is composing related essays and poems.

In 1986 Hoffmann began taping the television series *The World of Chemistry*, produced by the Educational Film Center in Annandale, Va. The program introduces a variety of chemical principles and theories, which are placed in historical context and are presented through experimental demonstrations and computer animation.

In front of a camera, Hoffmann seems awkward; his voice, which is usually soft and soothing, becomes high-pitched. "Our budget was too small to send me to acting school," he explained. Nevertheless, he has embarked on a new television project called *The Molecular World*. Still in the planning stages, it will include three prime-time programs.

Having made the transition from poetry to television and from organic to solid-state chemistry, Hoffmann, now 53, has earned celebrity status among chemists. In spite of his fame, he remarked that "it has not become any easier to publish a paper, nor, for that matter, a poem." —*Russell Ruthen*