The Spectrum

Volume 17
Issue 4
Winter 2004

Nobel Laureate
Roald Hoffmann

viewpoint

Few individual scientists have received as many accolades in the chemical community as Roald Hoffmann. A refugee from war torn Poland, Professor Hoffmann found his American dream through the Bronx School of Science, Columbia University and Harvard. While a twenty-five year old Junior Fellow of the Harvard Corporation, he collaborated with the late Robert Burns Woodward in what became known almost as soon as it was published as the Woodward-Hoffmann rules. The collaboration of an organic chemist like Woodward, who in days before on-line literature searching had an almost computer-like recollection of the scientific literature, and the young theorist Hoffmann, seeking to understand and explain, led to theories that have driven scientific research in many areas, including the photochemical sciences, since. Though Hoffmann will claim, too modestly, that he knew little organic chemistry when his rules were proposed, physical organic chemistry books, and even undergraduate organic texts, have not been the same since Woodward-Hoffmann.

Hoffmann is not shy about telling his story and complimenting the America that enabled his dream. Like many others, including my own ancestors, he found on the welcome shores of America a chance to develop his skills to the level of his own abilities and succeed.

As an educator I've been lucky enough to know more than my share of "real" Americans—young people who came here, studied at our universities, and then made America their home. Recently, I accompanied two of our former graduate students, both of whom are now employed in the area, as they took the oath of citizenship and became Americans. Each had lived his/her own life in countries where there were fewer freedoms than here. Each had seen his/her own parents persecuted for their religious beliefs. Finally, after conquering a new language and studying at our University, they achieved the time when they would no longer have to worry about an immigration officer, an expired visa, or a misplaced critical document. Now and forever they are "real" Americans.

In the recent American election much was said about immigrants. Some Americans have the peculiar view that *they and only they* are *real* Americans, and few from foreign shores need apply. But many here now are only here because immigration rules were more lax when their forefathers were admitted. One can only wish that these "real" Americans would be half as generous to others as the Americans of the past were to them.

That's why it is such a delight to tell Roald Hoffmann's story in this issue of *The Spectrum*. We are honored to feature such a distinguished scientist. We are equally as honored to highlight the opportunity America and its educational system offered him to succeed first in our university system and then as a Nobel Laureate. We remain optimistic that the same American opportunities will be available for many like him now and well into the future.

D. C. Neckers

special feature

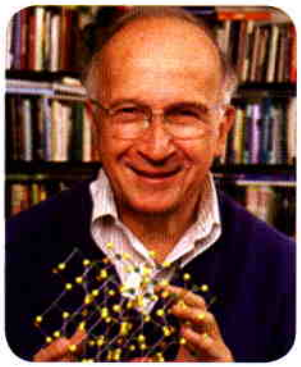
perspective on

a nobel laureate's world balanced between chemistry, poetry and philosophy

an interview with **Roald Hoffmann**

..."you have independently developed important theories of chemical reactivity. The concepts of frontier orbitals and conservation of orbital symmetry have revealed completely new aspects of the interaction between molecules in collision. Through drastic simplifications you have been able to make beautiful generalizations. From your theoretical work new tools have emerged of the greatest importance for the design of chemical experiments."

From the Nobel presentation speech by Professor Inga Fischer-Hjalmars of the Royal Academy of Sciences



Courtesy of Roald Hoffmann

On the Centenary of the Nobel Prizes in 2001, the Nobel Foundation decides to inaugurate a "Retro Nobel" for landmark discoveries made before 1901, when the first science prizes were awarded.

Selection should be a breeze. After all, wasn't science in the old days purer, done for its own sake, untainted by competition for priority and personal renown?

The Nobel Committee of the Royal Swedish Academy of Sciences gets a surprising answer when it decides to award the first Retro Nobel in Chemistry to the discovery of oxygen, which launched the modern science of chemistry. Who deserves it—Lavoisier or Priestley? What about the pharmacist Carl Scheele, who was the first person to prepare oxygen?

So let the play begin. We mean a play quite familiar to many a chemist. It is *Oxygen*, by Carl Djerassi and Roald Hoffmann. The action alternates between 1777 (when the king of Sweden brings the candidates and their wives to Stockholm) and 2001 (when the Retro Nobel Committee deliberates).

For Roald Hoffmann, collaboration on literary projects comes as naturally as scientific collaborations. Hoffmann discusses both in this interview with *The Spectrum*—ranging from his famous collaboration with Robert B. Woodward, which led to the Woodward-Hoffmann rules to the writing of *Oxygen* with Djerassi.

The Consummate Literate Chemist

Yes, Djerassi launched a career in writing in addition to a stellar life in science, which included invention of the birth control pill.

His novel, *Cantor's Dilemma*, for instance, is a whopping good read now in its 16th printing. Other chemists have had literary talent. Organic chemist Joseph F. Bunnett, for instance, once wrote a scientific article in verse. The Italian chemist Primo Levi also was a novelist. C. P. Snow, author of the Strangers and Brothers novels (and famous for lamenting the cultural gap between scientists and the literary/artistic world) started out as a chemist.

Roald Hoffmann, however, has delved further and deeper—as playwright, poet, essayist, writer of books—explaining science to the public and probing the links between science and religion, and presenter of a PBS television series on chemistry. One book, *Chemistry Imagined: Reflections on Science* (with artist Vivian Torrence) combines poems, essays, and articles with chemistry-inspired collages.

As he notes in *The Spectrum* interview, Hoffmann almost gave up the scientific life entirely for a degree in art history.

Winner of the 1981 Nobel Prize in Chemistry (shared with Kenichi Fukui) for predicting the outcome of chemical reactions, Hoffmann's scientific biography and many honors are well known. He is the only individual, for instance, to have received American Chemical Society awards in three different fields—the Arthur C. Cope Award in Organic Chemistry, the Award For Distinguished Service in the Advancement of Inorganic Chemistry, and the George C. Pimentel Award in Chemical Education.

Explorer of Chemistry

Roald Hoffmann was born in eastern Poland in 1937 and named after Roald Amundsen, the Norwegian explorer who was first to reach the South Pole. After surviving the Nazi terror and World War II, he settled in New York City in 1949, learned English (then his sixth language), went to Stuyvesant High School, the selective science school, and enrolled in Columbia University as a premed major.

Hoffmann found the science courses prescribed for premedical students uninspiring. Summer work at the National Bureau of Standards (now the National Institute for Standards and Technology) in Washington and Brookhaven National Laboratory helped spark Hoffmann's interest in research.

There were good chemistry teachers at Columbia, but he didn't encounter them until his last year there. However, the non-science courses at Columbia opened a seductive new world that nearly changed his career path.

From Columbia, Hoffmann moved to Harvard University for a master's degree in physics and a Ph.D. in chemical physics. Instead of an academic job, he stayed on at Harvard for three years as a junior fellow in the Society of Fellows. The decision was crucial. During that period Hoffmann began the collaboration with Robert B. Woodward that led to the Woodward-Hoffmann rules. They set the theory down in five landmark papers published in 1965 while Hoffmann was only 28.

The time at Harvard was creative in other ways. While at summer school in Sweden in 1959, Hoffmann began dating the receptionist, Eva Borjesson. They were married, and had two children (Hillel and Ingrid) during the Harvard years.

Hoffmann then moved to Cornell and became a full professor in 1968. At Cornell he found "a collegial department, a great university, and a lovely community," and stayed. He now is the Frank H. T. Rhodes Professor of Humane Letters.

The Spectrum:* Hide the word "Chemistry" in the last three Nobel Prize announcements, and they could be mistaken for the physiology or medicine prize. Discoveries about biological macromolecules won in 2002; cell membranes in 2003; and a cellular protein degradation system in 2004. Is that indicative of a broader trend in which chemistry is loosing its identity —as John Maddox, former editor of *Nature*, (among many others) worried?

Hoffmann: No, I don't think it is indicative of a broader trend—it is indicative of a deliberate decision by the Nobel Committee in Chemistry of the Swedish Academy of Sciences to define chemistry to include molecular biology and biochemistry. This infuriates some mainstream chemists. It doesn't bother me. Maddox's statement could be restated to say "Chemistry is so central and chemists so adaptable that they have followed their noses to become engineers, molecular biologists and materials scientists. They can solve complex problems of synthesis and mechanism, wherever these come up." We are not losing our identity. I still think there are inherently chemical ways of thinking, not reducible to physics, which characterize a chemist.

* In Maddox's words: "Chemists have done wonders in losing their identity in the rest of science. The practice of what still passes for chemistry seems to have been largely preempted by outsiders—physicists, quantum theoreticists, computer mavens, statisticians, instrument designers, laser experts, genetic engineers, medical researchers, psychiatrists, astronomers, materials specialists and a host of other species."

***The Spectrum:* Does that lead to any advice for students who are interested in chemistry and trying to decide on an undergraduate major or graduate field? A cell biologist can be a chemist these days just as surely as someone with a degree in organic chemistry.**

Hoffmann: And a chemist with a postdoc in cell biology can be a cell biologist. People never became chemists for the money, but for the fun—the stinks, the bangs, the colorful crystals, the understandable intricacy of isomerism, the exciting detective work of a structure determination, the brainteasing aspects of determining a reaction mechanism or plotting a synthesis. I think this will continue.

***The Spectrum:* Popular wisdom says that we need more chemists and chemical engineers. Is that need real? Should prospective chemistry majors perhaps be aware of the job market and look elsewhere?**

Hoffmann: No, we don't need more chemists. The demand is set by industry, which employs 70% of Ph.D.s. Our Ph.D.s are getting a job offer or two, on average. Not ten (that's what it would be if there were great demand). Our salaries would go up if there were fewer chemists produced and if our immigration laws were less porous. I think there are reasonable job prospects for our Ph.D.s now.

Atoms are nice, atoms are fundamental, but they're not chemistry. Chemistry is about molecules, the fixed but transformable way in which atoms get together for a while.

Roald Hoffmann, *Chemistry Imagined: Reflections on Science* (with Vivian Torrence, 1993)

***The Spectrum:* You began as a premed major at Columbia. What influenced your change to chemistry?**

Hoffmann: Summer research experiences at the National Bureau of Standards (now the National Institute of Standards and Technology, NIST) and at Brookhaven National Laboratory did it, by introducing me to research. While at NIST, I went over to the National Institutes of Health (NIH), and to my amazement discovered that you didn't have to have an M.D. to do medical research. I really didn't want to be a doctor, but there was family pressure to enter that profession. So slowly I worked up the courage to say I didn't want to be a doctor.

***The Spectrum:* Did you enjoy chemistry courses more than any others at Columbia?**

Hoffmann: No. The chemistry courses in my first years were routine. Only in my last year did I encounter intellectually interesting material and good teachers—in George Fraenkel, Ralph Halford and Ronald Breslow. Meanwhile, the world was opening up to me in the humanities—the world of literature and art, of Renaissance Italian painting, of Japanese literature, of poetry. My humanities courses were much more interesting than the science ones. It was wonderful.

***The Spectrum*: How seriously did you consider changing majors to art history?**

Hoffmann: Quite seriously. But... in the end, whereas I did have the courage to leave the premed program, I did not have the courage to enter the humanities. It's OK, I've come part way back!

***The Spectrum*: How did you and Robert B. Woodward begin that famous collaboration that resulted in the Woodward-Hoffmann rules? Did the collaboration teach any lasting lesson?**

Hoffmann: It's a story of some length, and you will read part of it in a reminiscence in a December 2004 issue of *Angewandte Chemie*. Woodward came upon the frontier orbital explanation of the stereochemistry of electrocyclic reactions by himself, and then came to me looking for a "more sound" theoretical basis for them. He was wrong—the simple argument he had was more powerful than the very approximate extended Hückel calculations I did. It took me a few joint papers to realize that—but the power of simple orbital arguments, and the joy of interaction with the chemical literature is perhaps the most important thing I learned from the collaboration with RBW.

***The Spectrum*: What are the essential elements for a successful collaboration?**

Hoffmann: In this case, a pair of helping hands/a mind (that's me) was transformed into a collaborator. In the case of a senior person and one much more junior (Woodward was 21 years older, about to receive the Nobel Prize, I was a new Ph.D., 26), the critical point in a collaboration is when the younger person tells the older one something the latter did not know. And the senior person has the sensitivity and honesty to acknowledge that idea as new. That is what happened in our collaboration, around the end of our first paper, when we discussed the two modes of opening of cyclopropyl cation to allyl. The papers that followed were a real collaboration.

***The Spectrum*: You were just 28 when those five landmark papers were published, and they had an immediate impact on organic chemistry. Did you feel any "how-on-Earth-can-I-ever-top-this?" concern?**

Hoffmann: At the time, of course not. In fact, I didn't think I was doing anything important, I was just solving another problem. It took about two years for me to realize that the work was significant. After that? Well, one just goes on. I have done many things since, always teaching, trying to understand, and building bridges within chemistry and outside of it.

> These chemicals we desire and fear (chemists call them compounds or molecules, once they are reasonably pure) are not the largest (the realm of astronomy), nor the smallest (part of physics). They are squarely, nicely in the middle, on our human scale. Which is why we care about them, not as distanced, hypothetical constructs, but in this world. Those molecules, of pharmaceutical or pollutant, are of just the right size to interact, for better or for worse, with the molecules of our bodies.
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> Roald Hoffmann, *The Same and Not the Same* (1995)

***The Spectrum*: In the popular stereotype, the phrase, "a literate scientist" is a profound contradiction. How accurate is the stereotype of scientists as culturally deprived?**

Hoffmann: In part true, in part not. Many scientists are musical performers, many are widely read. And I believe that in everyone there resides some longing for matters of the spirit. Science provides that only in part. Still, it doesn't hurt to encourage scientists to move beyond science fiction and Escher. And to try to understand the complexity of modern art and music, as complex as modern science. Notice that to me "complex" is a good word, more so than "simple."

***The Spectrum*: Would more humanities courses have any benefit for today's chemistry students, perhaps in opening new channels of creativity in the lab?**

Hoffmann: I don't think they would help them in the lab. But they would make the scientists eventually (students may not realize it right away) feel better about themselves as complete moral and spiritual human beings. And maybe then they would do better science.