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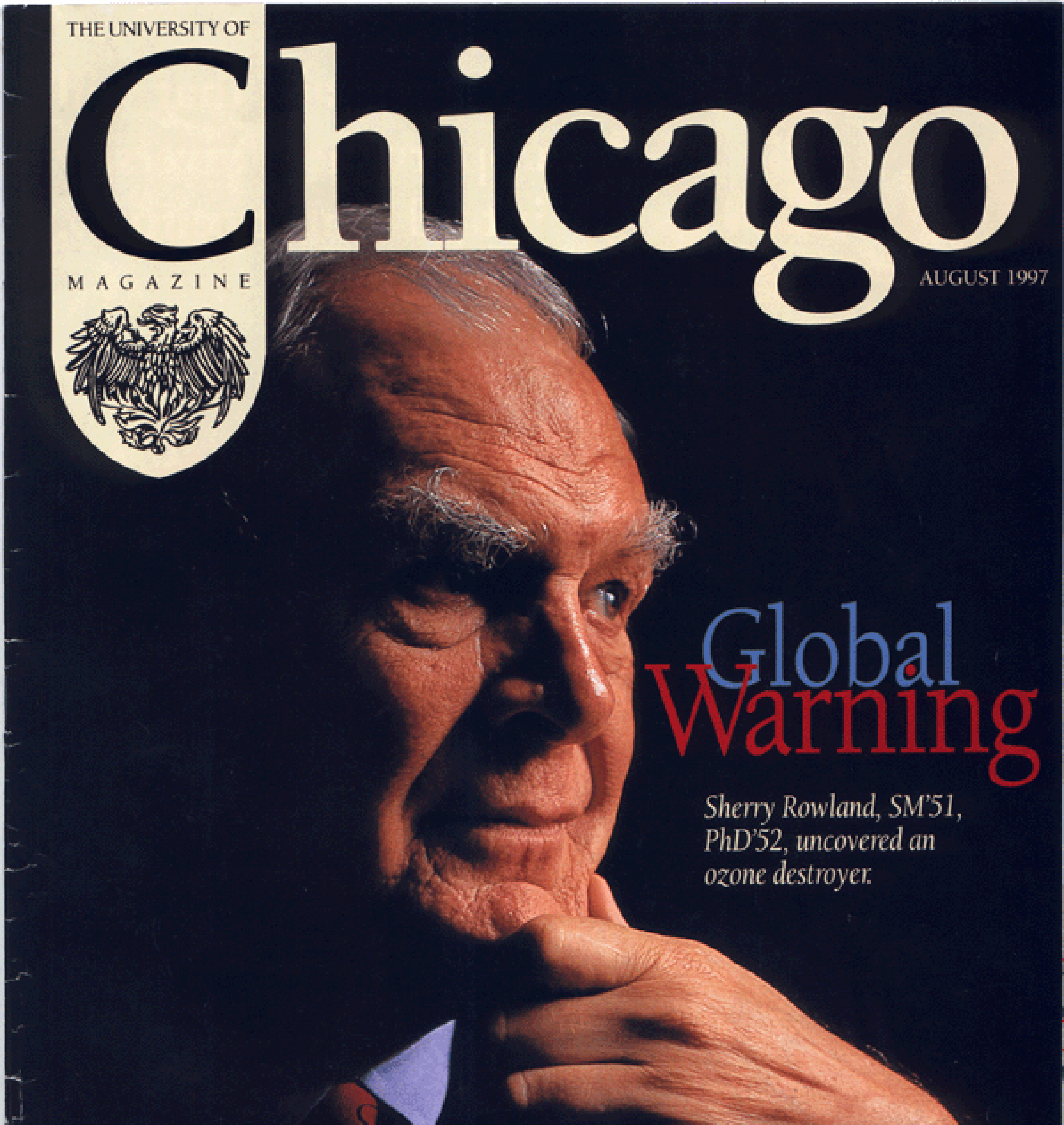

Global Warning

Sherry Rowland, SM'51, PhD'52, uncovered an ozone destroyer.

Clean-up Hitter

Long before F. Sherwood Rowland began to study chlorofluorocarbons, the man-made gases were a household force. His work in atmospheric chemistry made CFCs a household word—and halting their production a global issue.

By William Burton

Photograph by Dan Dry

What is the greatest sports team of all time? In basketball, some say it's the current vintage Chicago Bulls. Others cling to the Lakers of the Kareem era, or the Celtics of the 1960s. In baseball, many point to the Yankees of the 1920s. Some sports authorities argue that it's impossible to compare teams from different eras—and that trying to declare an all-time greatest team in *all* of sports is a hopeless exercise in comparing apples and oranges.

But what if we were to pursue the same frivolity with regard to more serious human endeavors: what if we tried to pick out the most important Nobel Prize–winning discovery? Planck's quantum theory of energy (physics, 1918) is the cornerstone of modern physics. Watson and Crick's elucidation of the double helix (physiology or medicine, 1962, with Maurice Wilkins) unleashed a biological revolution that is still unfolding in ways that astound. Shockley, Brattain, and Bardeen (physics, 1956) brought us the transistor, which not only ushered in the information age, but also made it easier for us to listen to—and argue about—ball games.

Most Nobel Prize winners are lauded for what they have given society, not for what they have taken away. Then there is the team of three scientists who shared the chemistry prize in 1995. F. Sherwood Rowland, SM'51, PhD'52, DSc(Hon)'89, recipient of the University's 1997 Alumni Medal, is one of those three laureates. Rowland—the Donald Bren research professor in chemistry and earth system science at the University of California, Irvine—along with his research associate Mario Molina and independent contributor Paul Crutzen of the Max-Planck-Institute for Chemistry in Germany revealed an insidious and potentially catastrophic danger lurking in our homes, right in our refrigerators, even in the personal-care products we sprayed on and around ourselves every day.

They discovered that the gases driving these devices—chlorofluorocarbons, or CFCs—could destroy the Earth's ozone layer, already known to protect plants and animals from lethal, DNA-damaging ultraviolet radiation. Loss of the ozone layer, they warned, could lead to disastrous health effects, crop failure, climate change, and disruption of the food chain.

Within a dozen years of their discovery, the ubiquitous man-made compounds at the center of this grim and seemingly far-fetched scenario—a family of industrial gases first introduced as refrigerator coolants in the 1930s and also used as foaming agents in the manufacture of car seats and other polyurethane products—would be shown to exceed even the devastation Sherry Rowland and Mario Molina had predicted.

The world's governments soon joined in an unprecedented agreement to eliminate this global menace. Production of CFCs in the developed world ceased, and the remaining trickle from developing countries is being phased out.

In the early 1970s, Rowland, already an expert in the chemical reactions of radioactive isotopes and their use as tracers of chemical and biological processes, was stepping down as chair of the Irvine chemistry department and looking for a new avenue of investigation. As a graduate student at Chicago—where he was best known as a standout varsity basketball and baseball player—he had studied under Willard Libby. Libby would later win a Nobel for developing the carbon-14 dating technique, which uses the formation, by cosmic rays, of a long-lived radioisotope incorporated into carbon dioxide to date plants and animal tissues up to 45,000 years old. Much of the carbon-14 chemistry takes place in the lower stratosphere, and Rowland now found himself drawn to environmental applications of radioactivity.

Attending a chemistry-meteorology workshop in early 1972, he learned that James Lovelock, a British biospheric scientist, had developed a highly sensitive instrument to measure trace organic compounds in the atmosphere. Taking air samples from shipboard in the North and South Atlantic, Lovelock had detected one particular CFC throughout the troposphere, the 6-to-10-mile-high layer of the atmosphere between the earth's surface and the stratosphere. Lovelock was enthusiastic about the finding: He thought the CFC molecule would prove an excellent tag for air-mass movements and wind direction, since its chemical stability would prevent its removal from the atmosphere. Rowland, however, saw the matter differently.

"I knew that such a molecule could not remain inert in the atmosphere forever," Rowland says, "if only because solar photochemistry at high altitudes would break it down." The next year, when he submitted his regular yearly proposal to the Atomic Energy Commission, which had supported his research for 17 years, Rowland posed a new question: What would eventually become of CFC molecules in the atmosphere?

With Molina, a photochemist from Mexico City who had just joined his lab, Rowland began investigating the atmospheric fate of CFCs. The two knew that, like all molecular gases, the CFCs could be broken down into their constituent atoms by short-wavelength ultraviolet radiation from the sun once they reached the stratosphere, from 12 to 23 miles up, where the sunlight is unshielded by the ozone layer.

After careful study, Rowland and Molina ruled out any chance that the CFCs might be rinsed out of the atmosphere by rainfall, as these organic compounds are insoluble in water. Nor was there any other known mechanism for the removal of the inert CFCs from the troposphere. Moreover, Lovelock's measurements suggested that the total amount of a particular CFC in the troposphere was, in fact, equal to the total amount of it *ever* manufactured—which by that time, for all CFCs combined, totaled several million tons.

Although heavier than air, the CFC molecules would eventually bounce up to the stratosphere, Rowland and Molina figured, and get zapped by the high-energy ultraviolet light, which would break off an atom of chlorine. Each free chlorine atom would immediately react with a molecule of ozone, a highly unstable form of molecular oxygen that contains three atoms rather than the usual two. This would initiate a lengthy and complex chain reaction, destroying many thousands of ozone molecules for every chlorine atom unleashed in the stratosphere.

Rowland and Molina shared a chilling realization: A major, possibly irreversible, catastrophe had already been set in motion. Working from rough calculations, they estimated that an eventual loss of approximately 20 to 40 percent of the ozone was possible. This was a few days before Christmas of 1973.

"It was like staring into a pit and not being able to see the bottom," Rowland recalls. "Molina and I had discussed the overall calculations, and we were looking for flaws, and each of us would sort of realize that as far as we could tell, there were no flaws.

"I'd come home at the end of the day," Rowland continues, "and my wife would ask me how the work was going. 'Good,' I'd say, 'but it might mean the end of the world.'" Her reaction, Rowland says, was to immediately throw out every aerosol can in the house.

"Fifteen down," he says, "six billion to go."

Initially, Joan Lundberg Rowland, PhB'46, was one of very few people to act quickly on the news. There was no urgent phone call to Washington. "I didn't know anybody," her husband explains. "Not anybody in power, not anybody in the press."

In January 1974, convinced of the veracity and gravity of their findings, Rowland and Molina submitted an article to the British journal *Nature*—where it languished for eight months. Even after publication, the news media paid little attention until the two chemists presented their findings at a September meeting of the American Chemical Society in Atlantic City.

By that time, they had calculated that if CFC production continued at the then current (peak) rate of about a million tons per year, between 7 and 13 percent of the ultraviolet-blocking ozone would be destroyed within a century. They told the meeting that society could expect a significant rise in skin cancer, crop damage, and perhaps even changes in global weather patterns.

Within a few weeks, their calculations for ozone loss were confirmed by Crutzen, a meteorologist then working at the National Center for Atmospheric Research and the National Oceanic and Atmospheric Administration in Boulder, Colorado, and by other groups as well. Still others produced numbers that suggested even more rapid destruction of the ozone layer.

Now the press took notice, as did the environmentalists, who called for an immediate ban on the purchase of CFC aerosol sprays. The National Academy of Sciences announced it would mount a full-scale investigation, and congressional hearings were soon under way.

Nor did the CFC industry remain inert. Its response was to insist that ozone destruction was just a hypothesis, based on computer projections—and that there was no proof the molecules would ever reach the stratosphere, let alone behave so malevolently if they did. The industry position was that CFCs should be regarded as innocent until proven guilty—prompting one government official to retort: "We cannot afford to give chemicals the same constitutional rights that we enjoy under the law." But government action was not forthcoming; it was not until 1978 that the U.S. unilaterally banned the use of CFCs in aerosol sprays. Other countries did not follow suit until the Antarctic ozone hole was found in 1984.

The 40-percent ozone depletion and the 10-percent increase in ultraviolet penetration discovered at the British Antarctic Survey's Halley Bay station would lead to the landmark Montreal Protocol of 1987, in which many of the world's developed nations quickly agreed to halve CFC production by 1999. In 1990, as evidence of ozone loss continued to mount, delegates took the protocol a step further, agreeing to a total phaseout by the year 2000. The catastrophic loss of ozone also quieted Rowland's aerosol-industry detractors, who had mounted a withering attack on him since 1974.

"One of the people in the industry in an interview suggested that [Molina and I] were probably agents of the KGB," Rowland recalls. He had spent much of that 11-year period testifying at congressional hearings and speaking at universities and scientific conferences around the world. He had been elected to the National Academy of Sciences and the American Academy of Arts and Sciences, and he received the American Physical Society's Leo Szilard Award for physics in the public interest. But he was also shunned by the chemistry community. From the time he and Molina published in 1974 until DuPont agreed to halt production of CFCs in 1988, he says, he did not get any applications from American graduate students or postdocs from outside the California system. "American grad students are pretty cagey," he says. Most of his university speaking invitations during that time came from toxicology or atmospheric-science departments.

Still, Rowland—a man well known for his patience—is magnanimous even to the point of defending his erstwhile industry adversaries. "Every young person I ever knew getting into chemistry or physics really thought that they were on the good side and were trying to make life better for people," he explains. "So it came as a disturbing shock to them that people were saying that some things that they had done weren't actually making life better, but worse."

Rowland says that in a world polarized between tree huggers on one extreme and midnight dumpers on the other, he is closer to being an environmentalist. But his natural home is with academic scientists; the 1974 *Nature* paper, he notes, was his 171st publication. In 1971 he even drew the ire of environmentalists by showing that levels of mercury found in tuna were in fact no higher than those in specimens preserved decades earlier.

Sherry Rowland, as he is known to everyone, was born in Delaware, Ohio, where his father was a professor and chair of mathematics at Ohio Wesleyan University. The younger Rowland entered Ohio Wesleyan at age 16, and because there were but 30 or 40 civilian males on campus, he says, he was able to make both the varsity baseball and basketball teams. After graduation came military service. Then, as had been foreordained by his family, he would continue his education. His parents had firm convictions that the University of Chicago, which each had attended, "was not just the best choice for graduate work, but the only choice."

"I just applied to Chicago," Rowland recalls, "and I went off, not knowing the name of anyone who was on the faculty or having talked with anyone who was there." His randomly assigned mentor was Libby, whom he credits with teaching him almost everything he learned about how to be a research scientist.

But not all of Rowland's time was spent in the lab. "I really ran around with the jocks on campus," he says. "I was playing over at the gym and found out I was eligible for the University basketball team. And then they started talking about baseball, and I ended up being the first baseman and clean-up

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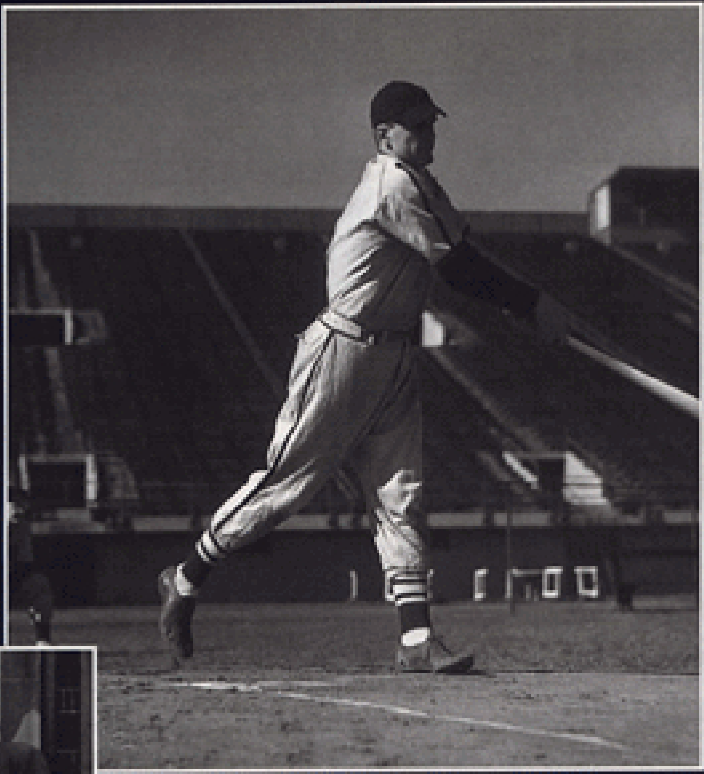
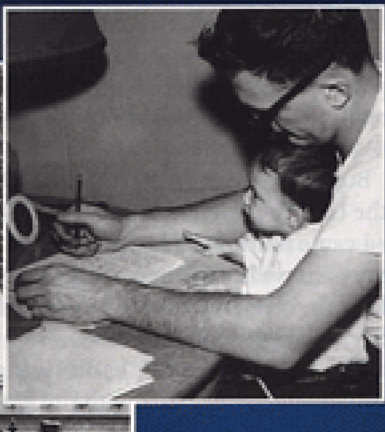


The chemist/Maroon baseball star (top) married Joan Lundberg, PhB'46, in June 1952, a few days after they appeared in a Chicago Tribune article on campus couples (they're the pair on the right, bottom); as a Princeton postdoc, Rowland (below) got help from daughter Ingrid, who now teaches art history at the U of C.



batter for three years." In 1950 he played for and managed the Oshawa Merchants a championship semipro team in Canada. How did all this sit with Libby? "He thought I was lazy, and with respect to chemistry that was probably true," Rowland admits. "I led a busy life." He and Joan were married on campus in what is now the Thorndike Hilton Chapel on June 7, 1952. They had two children; today their daughter, Ingrid, is an associate professor of art history at the U of C.

After a stint doing postdoctoral research at Princeton University, Rowland joined the faculty at the University of Kansas, where he rose steadily through the professorial ranks. In 1964 he went to the brand-new Irvine campus of the University of California as its chemistry department's founding chair.

Rowland followed advice from Libby: to deliberately strike out in a new research direction every few years. Yet he has remained interested in the chemistry of the atmosphere—and in environmental challenges. He is very concerned about global-warming scenarios caused by man-made carbon dioxide emissions. And his research team recently discovered that common liquid propane gas—the cooking and heating fuel leaking from millions of tanks that dot low-income neighborhoods around the world—is a critical component of urban smog.

The 70-year-old Rowland is currently foreign secretary of the National Academy of Sciences, and he has served as president and chair of the American Association for the Advancement of Science. His advice to young scientists who may be hard-pressed to discover something new in a crowded field: "Don't look under the light. Go out into the darkness."

For those of you keeping score at home, here's the wrap-up: Rowland recognized a problem where everyone else saw only blue sky, and life itself hung in the balance. A global effort mobilized by his predictions has, in his words, "put a cap on what goes into the atmosphere." And, even though he admits that "it's very hard, essentially impossible, to get back out of the atmosphere that which has already gotten into it," the good news is that Rowland's work may have spared the planet far graver damage.

How does that make him feel?

"Well that's as you can imagine," Sherry Rowland replies. "One would not have thought it possible for anyone to have done it, and to have been involved in doing it *oneself* is chastening and eye-opening and, I'd say, an area of satisfaction."

Spoken like a true champion.