Civic Scientist
précis

JAMES A. BAKER III INSTITUTE FOR PUBLIC POLICY
RICE UNIVERSITY

# $C_{60}$ — A Model for the Future

Robert F. Curl Jr., Ph.D., Sir Harold Kroto, Ph.D., and the late Richard Smalley, Ph.D., are world-renowned scientists, Nobel Prize winners and advocates for science in society. These three scientists were all members of the six-person team that discovered a new carbon molecule, buckminsterfullerene ($C_{60}$), which revolutionized carbon-based chemistry and established the new and exciting field of research known as nanotechnology.

In addition to their scientific achievements, these men have utilized their scientific reputation and expertise to further public engagement and understanding of science to better their communities, nation and world. Curl has advocated for environmental awareness, leadership, and science and math education reform. Kroto has dedicated his time to improving science and math education through the Vega Science Trust initiative. Smalley argued for the development of new technologies to address the world's increasing energy demands and was a significant proponent for the nation's and the world's support of nanotechnology.

It is because of these efforts to integrate science and society that Curl, Kroto and Smalley are the 2010 Civic Scientists as named by the Baker Institute Science and Technology Policy Program.

## *Nobel work: The discovery of $C_{60}$*

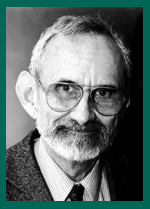
The discovery of $C_{60}$ was made possible by Smalley's invention of a supersonic cluster beam apparatus capable of creating and investigating the properties of clusters of any material. Its application to carbon clusters began with Kroto's interest in the formation of long-chain carbon molecules. In 1984, Curl, Kroto's colleague who was at Rice University, introduced him to Smalley and his invention. Kroto realized that this apparatus could simulate the process by which carbon was expelled into the circumstellar environment where the carbon atoms could form clusters. He believed that this was the process by which the long carbon-chain molecules that he had observed by radioastronomy were formed.

Kroto, Smalley and Curl conducted the carbon chain experiments suggested by Kroto with the help of three graduate students, Jim Heath, Sean O'Brien and Yuan Liu. In the course of these experiments, the team accidentally discovered evidence that a molecule with the chemical formula of $C_{60}$ was self-assembling in large quantities. It was clear from the evidence obtained during a 10-day period in September 1985 that the $C_{60}$ cluster must have a special structure that made it especially stable and chemically unreactive. A closed-sphere design was formulated for this uniquely stable cluster, which was dubbed buckminsterfullerene, after Buckminster Fuller, the American architect and inventor who popularized the geodesic dome. The paper on the discovery of this "buckyball" was written in two days and submitted for publication to the journal Nature.

The detection of $C_{60}$ led to the discovery of a new class of molecules known as fullerenes, solely composed of carbon in a cage-like arrangement. Measuring a billionth of a meter in diameter, these molecules suggested that there could be exciting new methods of self-assembly to make many other nanometer-scale structures. This, together with tremendous new advances in the ability to "see" nanometer-scale

*by Nathan Lo, Kara Calhoun, David Liou, Kenneth Evans, Kirstin Matthews, Ph.D., and Neal Lane, Ph.D.*

*Robert F. Curl Jr., Ph.D., is the Kenneth S. Pitzer–Schlumberger Professor of Natural Sciences Emeritus and University Professor Emeritus at Rice University. He is also a Baker Institute Rice Scholar.*





structures on surfaces, led Smalley to envision that the time was finally right to focus scientific interest and resources on the submicroscopic world of the nanometer scale. Thus, the new field of nanotechnology, which deals with the precise control and manipulation of matter on a nanometer (one billionth of a meter) scale, was born.

With applications in medicine, materials, energy environmental remediation and other areas, nanotechnology has the potential to revolutionize other technologies. In one distinct subarea of nanotechnology, the discovery of the $C_{60}$ and other fullerenes sparked innovative, carbon–based approaches to the synthesis of new materials, as well as new approaches for harnessing solar energy and targeting drug delivery in the body. The $C_{60}$ molecule, fullerene chemistry and nanotechnology are helping to improve the world we live in.

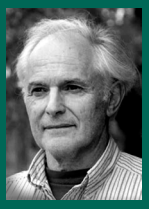
## *Robert F. Curl Jr.*

Robert F. Curl was born in Alice, Texas, in 1933. Growing up, Curl first developed an interest in science when he received a chemistry set as a gift in grade school. He spent so much time with the kit that he exhausted all the experiments provided with the set and mixed every possible permutation of chemicals. Curl attended Thomas Jefferson High School in San Antonio, where he continued to experiment with chemistry beyond the regular curriculum. He received special projects from his high school chemistry teacher and even performed stovetop research in his parents' kitchen. This exposure — and genuine interest at an early age — solidified Curl's dedication to science and began his outstanding career as a chemist.

Curl arrived at Rice University (then Rice Institute) as an undergraduate in 1950, excited by its academic reputation and free tuition. He excelled academically, graduating with a Bachelor of Arts in chemistry in 1954, and earned a National Science Foundation predoctoral fellowship to attend the University of California, Berkeley, to work with Kenneth Pitzer, Ph.D., who, later in his career, would serve as president of Rice. At Berkeley, Curl worked in both experimental and theoretical chemistry, graduating with a doctorate in 1957.

Curl held a postdoctoral position at Harvard University under E. Bright Wilson Jr., with a research focus on measuring barriers to internal rotation using microwave spectroscopy. In 1958, he accepted a job offer as an assistant professor in the Rice University Chemistry Department, and was promoted to full professor in 1967. Soon thereafter, he served as the first master of Lovett College. Later, he was thrilled to be named the first Kenneth S. Pitzer–Schlumberger Professor of Natural Sciences. In 2003, Curl was named a University Professor, Rice's highest academic title. The same year, he became a Baker Institute Rice scholar.

In recent years, Curl has been an advocate of K–12 science, technology, engineering and math (STEM) education reform, cleaner energy and climate change initiatives. He often speaks publicly about the need for climate change policy development, and makes presentations on the history and future of carbon. Curl has become progressively more active within environmental policy through the Baker Institute. In 2010, he and Dagobert Brito, Ph.D., Peterkin Professor of Political Economy at Rice University, published an article describing a simple model that can be used to estimate the cost of carbon dioxide constraints in the production of electricity (Economics of Pricing the Cost of Carbon Dioxide Restrictions in the Production



*Sir Harold W. Kroto, Ph.D., is currently Francis Eppes Professor of Chemistry at The Florida State University, conducting research in nanoscience and cluster chemistry as well as developing new approaches to science, technology, engineering and math educational outreach.*



of Electricity: http://www.bakerinstitute.org/BritoCurl-CO2ElecEcon). He has also advocated for the adoption of the STEM education reforms proposed by the The Academy of Medicine, Engineering and Science of Texas (TAMEST). And he is currently chair of the Advisory Committee on Research Programs of the Texas Higher Education Board.

Furthermore, throughout his tenure at Rice, Curl has shown a strong commitment to student life and the Rice academic community. He has served on several university committees and as chair of the Chemistry Department. Curl taught a course at Rice nearly every semester starting in 1958 until he went on full emeritus status in July 2008.

## *Sir Harold Kroto*

Born Harold Walter Krotoschin in 1939, Kroto grew up in Bolton, England, with his parents, who had fled Nazi Germany prior to his birth. He attended the prestigious Bolton School, where he enjoyed the arts, geography and gymnastics.

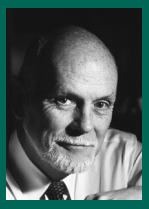
Kroto's interest in chemistry was piqued at a young age, eventually leading to his studies at Sheffield University. At Sheffield, he played tennis and was the art director of the school magazine Arrows. After earning his degree with first-class honors in 1961, Kroto continued on at Sheffield University to earn his Ph.D. in 1964 for his research in molecular spectroscopy under Richard Dixon, Ph.D.

Soon after, Kroto and his wife Margaret moved to Ottawa, Canada, for a postdoctoral position at the National Research Council Canada. Two years later, he moved to Bell Labs in Murray Hill, N.J., to continue research in spectroscopy.

In 1967, Kroto returned to England to take a position at the University of Sussex. The next few years in Sussex solidified Kroto's interest in pursuing science over the arts. At Sussex, he began the research that eventually led to his co-discovery of the $C_{60}$ molecule in 1985. This same year, Kroto became a full professor at the University of Sussex.

Kroto attributes his scientific success to a childhood full of science and engineering experiences. As a child, he grew up visiting his father's toy balloon factory, constantly immersed in a world of machinery. He also spent a lot of time playing with Mecanno, a construction toy that allows children to build working models and mechanical devices and that he believes are superior to today's Lego toys. The decline of Mecanno, he believes, is one reason for the decreased public interest in science in the United Kingdom in recent years.

In addition to Kroto's groundbreaking scientific contributions, he is also known for his use of the Internet to improve science education. Using his prestige, and later his fame from the Nobel Prize, Kroto established the Vega Science Trust in 1995 (http://vega.org.uk/). The Vega Science Trust creates engaging science education videos that extend a fundamental understanding of the physical world to the general public. The trust has helped produce more than 200 scientific educational films, including many series run on BBC television. Based on this work, Kroto in 2001 received the Michael Faraday Award from the U.K. Royal



*Professor Richard E. Smalley, who joined Rice University in 1976, was a university professor and a professor of chemistry and physics. He died in 2005 after a long battle with cancer.*



Society, which is given annually to a scientist for excellence in communicating science to the general public. He was also knighted by the Queen of England in 1996. Kroto continues to lead the Vega Science Trust as the chair of the board.

In 2004, Kroto accepted a professorship at The Florida State University (FSU), where he continues to teach and research. He gives at least one lecture to every incoming freshman class. In 2007, he established the Global Educational Outreach for Science Engineering and Technology (GEOSET) in conjunction with FSU (http://www.geoset.info/). GEOSET uses technology to create easy access to a broad spectrum of educational videos through the Internet with a focus on science. Kroto also designed GEOSET as a way of transforming how learning materials are distributed with the goal of becoming a new educational medium where academic resources are centralized at one location.

Through the Royal Society, Kroto has pushed heavily for educational reform in the United Kingdom, often specifically advocating against efforts to include the teaching of creationism instead of, or in addition, to evolution. He has also been a visible proponent of funding nanotechnology research amid controversies related to environmental and health risks.

Kroto is also director of the Florida Center for Research in Science, Technology, Engineering and Mathematics Education (FCR–STEM) and an active member of the National Advisory Committee on Cultural and Creative Education. He lectures in universities across the country and abroad, advocating improved science education throughout the world.

## *Richard Smalley*

Richard Errett Smalley was born on June 6, 1943, in Akron, Ohio, to Esther Rhoads and Frank Smalley Jr. The younger Smalley formed ideas about nature and how the world worked from his parents. He recounted how his mother would frequently tell stories about her favorite scientists and how his father taught him to build and fix gadgets. Although his mother was the initial person to pique his interest in science, it was the launch of Sputnik in 1957 that prompted Smalley to make science his career.

At age 18, Smalley began working in the organic chemistry laboratory of his aunt, Sara Jane Rhoades, Ph.D., at the University of Wyoming. Rhoades inspired Smalley to attend Hope College in Holland, Mich., but he later transferred to the University of Michigan in Ann Arbor after two of his favorite teachers left Hope College. He graduated from the University of Michigan in 1965 with a Bachelor of Science in chemistry.

After working at Shell Chemical Company, Smalley attended Princeton University in 1969 to obtain his doctorate. During this time, he learned more about chemical physics and the intense style of research demanded in the field. Upon completing his Ph.D., Smalley worked with some of the brightest minds in chemistry and developed his interest in molecular beam apparatuses at The University of Chicago. In 1976, Smalley came to Rice University as an assistant professor in the Chemistry Department, where remained for the rest of his academic life.

Following the discovery of the "buckyball," and especially after receiving the 1996 Nobel Prize in chemistry, Smalley shifted his career and influence toward advocating for public support of research in

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nanotechnology. Even after being diagnosed with leukemia in 1999, Smalley testified before Congress regarding nanotechnology and worked with Neal Lane, Ph.D., then science adviser to President Bill Clinton, to gain support for the National Nanotechnology Initiative (NNI). The NNI, which was created in 2000, promotes and coordinates nanotechnology research in the federal agencies funded through the NNI legislation (http://www.nano.gov/).

Smalley was also responsible for the creation of the first organized nanotechnology center in the world, Rice University's Center for Nanoscale Science and Technology, which was renamed The Richard E. Smalley Institute for Nanoscale Science and Technology after his death in 2005 (http://cnst.rice.edu). He was also helpful in the establishment of the Center for Biological and Environmental Nanotechnology at Rice University (http://www.cben.rice.edu). Both organizations are dedicated to advancing the application of nanoscience to challenges in society and to furthering public understanding of nanotechnology. At the Smalley Institute, his legacy continues through the institute's active efforts to attract and encourage researchers using nanotechnology to tackle civilization's greatest challenges involving energy, water, environment, disease and education. At the present, 150 world-class science and engineering faculty work in a close collaboration fostered by the Smalley Institute.

Smalley was passionate about the need to develop new technologies to address the world's future energy needs, emphasizing the duality of necessary policy changes in Washington, D.C., and more scientific research in the field. In addition, he was a strong advocate for improving science education in the United States, and continued to use his influence to advance the cause of expanding public understanding and support for science. While meeting with students, Smalley was often heard to encourage careers in science and engineering through his strongly held adage: "Be a scientist. Save the world."

## *Civic Scientists*

These three scientists — Robert Curl, Harold Kroto and Richard Smalley — embody the concept of a civic scientist. A civic scientist, according to Neal Lane, the senior fellow in science and technology policy at the Baker Institute and former science adviser for President Bill Clinton, "is someone who uses his or her knowledge, accomplishments and skills to help bridge the gap between science and society."

There are many ways to be a civic scientist. Curl utilizes his science and his fame as a Nobel laureate to inform the public on the matters of energy, climate change and K-12 science education, while encouraging policymakers to support research funding and sensible legislation on such matters. Moreover, he engages in research to provide a basis for his arguments. Further, Curl's emphasis on science education is evident in his involvement with Rice students through a multifaceted approach to teaching and mentorship.

Kroto exemplifies the concept of a civic scientist with his dual emphasis on advancing science while engaging the larger public in an effort to encourage scientific understanding and enthusiasm. His passion for science and math education extends to young people, whom he actively seeks to engage in scientific discovery. Further, his work with the Vega Science Trust and GEOSET has helped foster an understanding of science that raises the level of education in science and math and, at the same time, helps the public participate in the process of making informed policy decisions. Indeed, Kroto has been directly engaged in science policy, especially on issues relating to education.

Smalley demonstrated his role as a civic scientist through his relentless push for funding nanotechnology through the National Nanotechnology Initiative and support for scientific advancement in alternative energy research for the United States and the world. His recognition of the potential and importance of nanotechnology resulted in his extensive involvement in science policy, culminating in his testimony at Congress for the funding of nanotech. Smalley was also involved in a push for the science education of our youth.

The civic scientist plays an integral role in bridging the gap between science and the public. Through a mutually beneficial relationship, advancements in science can be effectively utilized to create positive change for society. These civic scientists facilitate the conversion of the advancement in science to the advancement of society. There are hundreds of good stories about civic scientists in the United States and elsewhere in the world. But, as science and technology increasingly impact the lives of people — how they live, work, communicate, entertain themselves and cope with world around them — the need for more civic scientists is ever greater.

## *About the Civic Scientist Program*

The Baker Institute Science and Technology Policy Program, as a part of its Civic Scientist Program, sponsors an annual lecture series featuring high-profile scientists who have taken time out of their scientific lives to reach out to the public, young and old, and inform policymakers in all levels of government. Previous civic scientist honorees include: Arden Bement, David A. Ross Distinguished Professor and director of the Global Policy Research Institute at Purdue University, as well as former director of the National Science Foundation; Shirley Ann Jackson, president of Rensselaer Polytechnic Institute and former chair of the Nuclear Regulatory Commission; and Bruce Alberts, editor-in-chief of Science magazine and former president of the U.S. National Academy of Sciences from 1993 to 2005.

The goal of the Baker Institute Civic Scientist program is to encourage scientists, engineers and other technical professionals at Rice, and across the country, to engage in public policy and outreach, as well as to provide the Houston community with an opportunity to hear leading scientists discuss their fields and careers. Hopefully, the series will also remind those who determine federal and state budgets of the importance of funding scientific research and education and insuring that government policies are based on the best science. For more information on the Baker Institute Civic Scientist program, visit the program's website: http://www.bakerinstitute.org/civic-scientist.

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