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Alan Davison. 24 March 1936 — 14 November 2015

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ALAN DAVISON
24 March 1936 — 14 November 2015
In 1958 Professor Alan Davison started his research career at an exciting time for the field of organometallic chemistry. New developments in spectroscopy, instrumentation and techniques to manipulate materials in controlled environments to avoid reaction with water or oxygen were becoming widely available. Controlling exposure of an element with highly reactive oxygen facilitated the isolation, characterization and discovery of an abundance of unknown compounds. Alan was an insightful and talented synthetic chemist and made many new and interesting organometallic compounds. He used the earliest commercial nuclear magnetic resonance instruments to characterize the then poorly understood transition metal hydrides and also to identify the earliest fluxional organometallic molecules. In 1970 he entered a collaboration with Professor Alun G. Jones, a nuclear chemist at Harvard Medical School, to characterize and develop the chemistry of technetium. They made a major discovery of technetium molecules which had the ability to selectively locate in human heart muscle, thereby vastly expanding the practice of nuclear medicine to a global community. Professor Alan Davison was also widely known for his outstanding qualities as a teacher and mentor.
BACKGROUND AND EDUCATION

Alan Davison was born in Ealing, England, on 24 March 1936, the only child of John William Davison (1898–1984), a draftsman from Durham, England, and Mrs Ellen Jane (Woodley) Davison (1907–1976), a seamstress from Kenfig and Port Talbot, South Wales. His paternal grandparents were Joseph Davison (born 1874, a furniture maker) and Mary Eleanor (Carr) Davison (born 1874) of Low Fell, Newcastle, England. Alan’s maternal grandparents were James Thomas Woodley (born 1881, Serviceman in the Boer War) and Mrs Ellen (Fuell) Woodley (born 1883) of St Marylebone, London.

Alan’s parents moved to South Wales shortly after he was born. After school, as a practical and enterprising young lad, he went to work in the laboratory of a steel mill in South Wales to augment the family income. Fellow workmen encouraged him to attend Neath Technical School and to accept a scholarship to the recently established (1920) University of Swansea. In 1957, Alan met and married Frances Elizabeth Griffiths (11 January 1935–17 December 1995). Upon graduation from Swansea, Alan was awarded a Royal Scholarship to Imperial College in London where he obtained his PhD in the field of inorganic chemistry in 1962 from Sir Geoffrey Wilkinson (1921–1996). Some of the students in Wilkinson’s research group at the same time as Davison were Martin Bennett FRS, Dennis Evans FRS, Ray Colton, Malcolm Green FRS, Bill Griffith, Eddie Abel and John Osborn. All these later became university professors in chemistry and contributed to the birth of modern organometallic and inorganic chemistry. Geoffrey Wilkinson, jointly with E. O. Fischer, was awarded the 1973 Nobel Prize in Chemistry.

In his research as a graduate student, Alan learned the skills required to synthesize organometallic transition metal compounds that were especially sensitive to water and oxygen. His main focus was on transition metal carbonyl compounds. After submission of his PhD thesis in 1961, he was advised by Geoffrey Wilkinson, who had spent his early academic years in the United States at both Harvard University and the Massachusetts Institute of Technology (MIT), to accept a position as an instructor in chemistry at Harvard University. He moved to Massachusetts in August 1962.

EARLY CAREER

Alan worked at Harvard University from 1962 to 1964, during which time he teamed up with Richard H. Holm to study metal complexes containing dithiolene ligands of relevance to bioinorganic chemistry. They used electron paramagnetic resonance (EPR) spectroscopy to conclude that, in the case of a nickel complex, the unpaired electron was metal-based (1, 2)*. In a paper tautly entitled ‘The myth of nickel(III) and nickel(IV) in planar complexes’ (Stiefel et al. 1965), Harry Gray, ForMemRS, at the California Institute of Technology (Caltech), came to a different conclusion from Holm and Davison, suggesting that the unpaired spin was ligand- rather than metal-localized. This academic rivalry ignited a competitive but collegial debate that continued for many years and sparked a mutual good-natured friendship between the chemists.

In 1964 Alan was appointed Assistant Professor in Inorganic Chemistry at the MIT. There his research returned to organometallic chemistry. He was particularly proud of his

* Numbers in this form refer to the bibliography at the end of the text.
Figure 1. Photograph of Al Cotton, Dietmar Seyferth and Alan Davison, colleagues on the MIT faculty standing in front of an early NMR spectrometer, ca 1966.

determination of a manganese–hydrogen bond distance with what was the first neutron diffraction study on a metal carbonyl hydride (4). The nature of the metal–hydrogen bond plays a central role in organometallic chemistry and Davison’s research in this area helped to establish our understanding that the hydrogen atom is as stereochemically active as a larger ligand and not buried within the valence electron shell of a metal atom. Other noteworthy contributions in these early years were his fundamental studies at the intersection of transition metal and boron chemistry. While studying the carbon–metal binding properties of cyclic-hydrocarbons (5), he expanded to the reactions of metal complexes with borane clusters (8) and synthesized a novel but stable compound in which the iron tricarbonyl unit replaced an apical BH moiety of pentaborane-9 (9). This was an early demonstration of the isolobal principle developed by Roald Hoffmann, ForMemRS, as described in his 1976 Nobel prize lecture. The molecule was featured on the cover of the book *Chemistry of the Elements* (first edition) by Greenwood and Earnshaw, a very rare honour at the time. Years later, Alan Davison applied his transition metal boron chemistry experience towards applications in medicine in the field of boron neutron capture therapy (BNCT) (33, 34).

One of Alan’s early significant contributions was the use and deciphering of information from the then new physics tool, nuclear magnetic resonance (NMR) spectroscopy (figure 1). In a classic paper (3) co-authored with F. Albert Cotton, Stephen J. Lippard and others, the problem of the NMR equivalence of all protons in a non-sandwich bonded cyclopentadienyl ligand was solved in a way that gave birth to a concept of stereo-chemical non-rigidity and fluxionality, now a widespread feature across a broad area of organometallic chemistry.

In a series of publications, Davison used ferrocene as a building block in the design of a new class of bidentate phosphine ligands (5–7). In this way, the sandwich complex was employed as a redox-active linker between two phosphorus atoms whose lone electron pairs could bind to another transition metal centre; this strategy is still utilized frequently today in the quest for new tailored ligands. The exploration of a variety of research and reactivity of new metal complexes supported Davison’s promotion to full Professor at MIT in 1974. He
continued to teach undergraduate and graduate chemistry subjects and perform research at MIT continuously for another 31 years, followed by Professor Emeritus for a further 10 years.

**RESEARCH IN NUCLEAR MEDICINE CHEMISTRY**

In 1970, across town at Harvard Medical School (HMS), the clinical teaching faculty organized the Joint Program in Nuclear Medicine (JPNM) as a training and research programme with several prominent hospitals in Boston, Massachusetts. Collaboration between institutes was designed to advance the study and practice of the rapidly growing field of nuclear medicine and to facilitate the collaboration of researchers in radiology, radiochemistry, radiation biology, radiation physics and internal medicine. The Harvard JPNM was founded by S. James Adelstein, at the time Associate Professor of Radiology at HMS. In 1971 Dr Adelstein recruited a young chemist named Alun G. Jones (PhD Nuclear Chemistry 1969, University of Liverpool, England) to the JPNM. As an assistant professor, in 1974 Jones sought to collaborate with fellow Briton Alan Davison to access the synthetic and theoretical expertise of inorganic chemistry at MIT. About this time Davison, and a large number of inorganic chemists, were starting to model and understand the essential nature of metal centres to the function of enzymes in biological systems (10, 11) so it seemed natural for Professor Richard Holm of the Harvard Chemistry Department to refer Alun Jones to MIT’s Professor Davison.

Davison and Jones brought together the fields of classical chemistry and radiological sciences to provide a rational understanding of the applications of the newly available isotope of $^{99m}$Tc to the field of nuclear medicine. The element technetium is a metal and right in the middle of the periodic table; however, all of the isotopes of technetium are radioactive (the longest lived, $^{98}$Tc, has a half-life of 4.2 million years), thus any technetium trapped in the formation of the Earth had long since decayed prior to the appearance of life. This meant the interaction of technetium in the human body was unknown, as was the nature of the metal’s reactivity. Although the existence of element 43 was predicted by Russian chemist Dmitri Mendeleev (1834–1907), its properties and chemistry were basically hypothetical until the 1930s and the discovery of controlled transmutation of the elements (Segrè & Seaborg 1938).

Following the development of the atomic bomb in the 1940s, the United Nations’ Atoms for Peace programme of the 1950s focused on applications for the peaceful use of radioactivity (Myers 1979). The primary isotopes of interest were nuclides of iodine because of their critical impact as fallout from a nuclear weapon. However, of all the isotopes being studied, $^{99m}$Tc had by far the best nuclear properties (six-hour physical half-life) for imaging humans with the newly developed ‘Anger camera’, because the 140-keV gamma photon had sufficient energy to penetrate the body and not interact or generate significant reactive ions, yet was low enough in energy to be efficiently detected (Anger 1957).

The practical aspect of widespread availability of the short-lived $^{99m}$Tc was addressed with the discovery in 1960 of the $^{99}$Mo/$^{99m}$Tc generator by Powell Richards at Brookhaven National Laboratories (BNL) in New York (Richards 1960). In this chromatographic separation, the long-lived parent radionuclide $^{99}$Mo ($t_{1/2} = 66$ h, as Na$_2$[MoO$_4$]) was adsorbed on alumina. Following beta-particle emission, each molybdenum atom mutates to the short-lived daughter nuclide $^{99m}$Tc ($t_{1/2} = 6$ h), which is rapidly separated from [MoO$_4$]$^{2–}$ in isotonic saline as
[TcO$_4$]$^-$ is the most stable chemical form of technetium, in the presence of water and oxygen, as the oxidation state of seven in the compound Na[TcO$_4$]. The pertechnetate anion has a similar size and charge as the iodide anion, and is similarly concentrated in the thyroid of mammals following intravenous injection. The dramatic tissue targeting and visualization properties of pertechnetate inspired researchers to empirically add almost any metal chelate available with a reducing agent, and observe the distribution in animals. The inventor of the first rapid process to make different pure compounds of technetium, William C. Eckelman, coined the phrase ‘instant kits’ and their biological evaluation as the ‘chromatographic rat’ (Eckelman & Richards 1970). These rapid ‘kits’, in combination with the $^{99m}$Tc generator, opened the path to developing numerous practical applications to image and diagnose a variety of human diseases. The conventional study of $^{99m}$Tc chemistry was complicated by the fact that the mass of technetium eluted from a typical $^{99m}$Tc generator was in the range of picograms, which was a far lower concentration than spectroscopic techniques of the day could detect.

Using the empirical ‘chromatographic rat’ approach, by the mid 1970s organ-specific visualization by various $^{99m}$Tc–chelate compounds was being studied by multiple researchers. The initial Davison–Jones collaboration focused on elucidation of the structures of the species produced in the early technetium kits, including the kidney- and bone-seeking agents. About this time, Davison obtained several milligrams of the longer-lived nuclide $^{99}$Tc ($t_{1/2} = 211\,000\,y$) from the US Department of Energy and, along with graduate students Harvey S. Trop (PhD 1979, MIT), Chris Orvig (PhD 1981, MIT), Bruno V. DePamphilis (PhD 1981, MIT) and James W. Brodack (PhD 1981, MIT), began synthesizing technetium compounds in the higher oxidation states to identify the structures in clinical $^{99m}$Tc ‘instant kits’ (12–14). Initially, to make tissue-specific drugs these kits were approved on the basis of safety and efficacy to localize in designated organs, but the exact structure of the technetium-containing compounds was unknown because the concentration was too low to perform classical spectroscopy. Davison and Jones usually began with the classical chemistry and spectroscopic characterization conducted in labs at MIT, using macroscopic quantities of the long-lived nuclide $^{99}$Tc, and then translated to the tracer level using the shorter-lived isotope $^{99m}$Tc for biological evaluation in Jones’ lab at HMS (15–19). This was more difficult than implied because the products of technetium reactions change, as the element tends to undergo metal–metal bonding at higher concentrations with the generation of oxygen-bridged, multi-metal centred complexes. However, in the very dilute conditions of technetium from a $^{99}$Mo/$^{99m}$Tc generator as in the ‘instant kits’, kinetically stable mono-nuclear technetium complexes formed with the excess chelate before the metal could self-react.

Davison and Jones are best known for their work with six-coordinate isocyanide complexes of technetium(I), research that led to the development of $^{99m}$Tc-SESTAMIBI (Cardiolite®), the first successful $^{99m}$Tc-based heart imaging agent. $^{99m}$Tc-SESTAMIBI is currently used worldwide and known as the gold standard for myocardial perfusion imaging that helped propel the field of nuclear cardiology. Prior to 1982, it was reported that quaternary ammonium compounds accumulated in heart muscle and there were also reports in the 1960s by the Australian chemist, Sir Ronald Sydney Nyholm FRS, on the preparation of cationic octahedral complexes of the form [Tc(diars)$_2$X$_2$]$^+$. Although no one believed technetium cationic complexes would resemble hydrated [K$^+$] or the ammonium cation, Davison’s graduate student, Michael Abrams (PhD 1982, MIT), proceeded to make some Tc$^+$ complexes. He isolated and characterized several 6-coordinate, lipophilic cationic complexes of technetium(I) alkylisocyanides (20). More importantly, he made these compounds in almost quantitative
yields, very rapidly, starting from sodium pertechnetate in water and the presence of air. A fast, efficient synthesis was required in view of the short half-life of the radioactive technetium isotope. There was substantial scepticism at the time that technetium (+1) compounds could not be made pure or would not be stable in water.

The cationic isocyanide–technetium complexes enabled the in vivo evaluation of biological distribution in animals and the observation of accumulation in normal healthy heart muscle. The prototype cationic Tc-99m-diars, reported by Nyholm, was almost simultaneously found to show similar myocardial accumulation in virtually every species tested (including non-human primates), except humans. Despite discouraging setbacks at targeting of human heart muscle by numerous researchers, Davison and Jones (with the help of John Lister-James PhD) moved ahead with testing of the t-butyl-isocyanide compound in human volunteers at Brigham and Women’s Hospital in Boston. In fact, the first volunteer was the Director of the JPNM and Dean at HMS. The first human images were actually better than the animal models predicted, although there was a substantial accumulation and retention in the lungs and liver that interfered with clear images of the apex of the heart muscle (21). The third volunteer was Alan Davison himself, who performed the first technetium-exercise imaging study. A copy of the whole-body scan of Alan Davison in 1984 is reproduced in figure 2.

The initial successful human heart images in 1984 inspired another of Davison’s graduate students, James Kronauge (PhD 1987, MIT), to synthesize and test various functionalized isocyanide compounds, resulting in a second generation of compounds with less lung retention and rapid hepatobiliary clearance (22). Support from industry (DuPont Pharma) accelerated at this time and, with help from former Davison students Timothy R. Carroll (PhD 1984, MIT) and Karen Linder (PhD 1986, MIT), a third generation was identified and a rapid transmetalation process was developed to produce a stable freeze-dried formulation and subsequent commercial kit (Kiatt et al. 1989; see figure 3).

Industrial support from the DuPont Pharmaceutical company for the commercial manufacture and distribution of kits, along with the design and execution of objective multicentre clinical trials, enabled the correlation of myocardial image defects with blood flow blockage in suspected heart attack patients. Following compilation, statistical analysis and submission of the clinical data, the diagnostic imaging agent obtained US Food and Drug Administration (FDA) approval in 1990 to identify the location of suspected myocardial infarcts. In the 1980s testing to support FDA approval of Cardiolite was only required to demonstrate clinical safety and efficacy to visualize the myocardium in proportion to blood flow and thus potentially identify coronary blockage. Once the site of blockage (or specific coronary artery) has been identified, the blood flow could be restored by either coronary artery bypass surgery or, more recently, by percutaneous transluminal coronary angioplasty (PTCA). PTCA is a procedure where a long narrow tube (or catheter) is threaded through a femoral artery in the leg, up the blood vessels to the aorta and into the coronary artery at the site of blockage. Once the guiding catheter is in place, a balloon catheter is advanced through the blockage site and inflated to compress the blockage and expand the artery. Then the balloon is deflated and an expandable fibre mesh or stent may be placed within the coronary artery to keep the vessel open.

The combination of the imaging test and revascularization procedures to open up blocked coronary arteries allows blood to re-perfuse the tissue and supply oxygen and nutrients to repair the heart muscle. The appropriate use of diagnostics and intervention has not only saved millions of lives over the years but also dramatically improved the quality of life for these
Figure 2. Whole-body two-dimensional image of the first-generation technetium heart agent Tc(t-butyliosocyanide)$^{+1}_6$ in the third healthy volunteer. Note the chamber or ‘donut’ shape above and to the right of the very bright liver (the patient is facing us). The line up the subject’s left arm is activity retained in the vein following intravenous injection. (Photograph provided by J. Kronauge.)

patients. In fact, Alan Davison himself received the approved drug the second time as a heart attack victim about 11 years after its discovery. So, effectively, you might say, the drug he discovered helped extend his life by another 18 years.

Although Cardiolite was effective at localizing blocked coronary arteries, the mechanism of heart muscle accumulation and retention was pure speculation. From 1988 to 1995 Davison collaborated with researchers at Brigham and Women’s Hospital (including David Piwinca-Worms, Mary L. Chiu and James Kronauge) to identify the uptake mechanism and subcellular localization of myocyte accumulation (26, 30). The commercial availability of Cardiolite kits and the rapid escalation of myocardial perfusion imaging (MPI) led to the development of the field of nuclear cardiology and a dramatic increase in the practice of
nuclear medicine. The worldwide use of Cardiolite was about 40 million procedures in 2010 (two years after it went generic) or about 20 million procedures in North America alone.

Shortly following regulatory approval for the clinical diagnosis of heart attack patients, clinicians began to observe unusual focal accumulations or ‘hot spots’ in nearby regions of the chest that turned out to be tumours. Cancer cell biology studies in Alun Jones’s lab at Harvard revealed accumulation of $^{99m}\text{Tc-SESTAMIBI}$ in the mitochondria of highly metabolic and rapidly growing tumour cells, but also rapid clearance in cancers that tended to exhibit multi-drug resistance to chemotherapeutic agents (28, 32). $^{99m}\text{Tc-SESTAMIBI}$ was subsequently clinically tested and approved for imaging thyroid and breast cancer, where it is highly valuable in visualizing tumours in women with dense breasts; that is, when mammography is inconclusive.

The collaboration between Davison and Jones was uniquely productive because of the synergy between their personalities. Although their mannerisms seemed quite different, they accentuated each other as Davison had an unbridled imagination and Jones provided the meticulous organization and follow through required to present a cognizant research proposal to obtain extramural funding to support the research laboratories. After almost 15 years of collaboration, the two British expatriates received an unsolicited Method to Extend Research in Time (MERIT) Award from the US National Institutes of Health (NIH). MERIT awards were designed to provide long-term grant support to investigators whose research competence and productivity are distinctly superior and who are highly likely to continue to perform in an outstanding manner. NIH staff and members of national advisory councils identify candidates for the MERIT Award during the course of review of competing research grant applications submitted to the US Public Health Service (PHS). This was of substantial value beyond peer recognition, because the burden of continuously generating and submitting proposals can distract and drain resources for completing or expanding a research topic. The focus of the MERIT Award was for synthesizing new technetium compounds and exploring their structure–activity relationships in biological systems. The picture in figure 4 shows Jones and Davison at an award presentation in 2006.

Figure 3. Three generations of technetium(I) lipophilic cations discovered by Davison that led to the development of Cardiolite, an imaging agent to localize coronary artery blockage and diagnose heart attacks due to myocardial infarction.
The discovery of Cardiolite attracts the most attention because of its commercial success, but Alan continued to explore and define the nuances of technetium chemistry for another decade. A continuous parade of talented students and post-doctoral fellows cycled through his laboratories at MIT and shared Alan’s love of chemistry and camaraderie. Alan preferred to keep his research group small, usually fewer than six students, and although he did not relish formal group meetings he enjoyed mentoring young chemists and fed off their enthusiasm. Along with faculty members on visiting sabbaticals, he continued to apply the power of improving technologies to study the behaviour of complex chemical and biological systems. Along with John Thornback (Loughborough University, England) and students Ron Pearlstein (PhD 1988, MIT) and Lynn O’Connell (PhD 1989, MIT) he studied the NMR properties of $^{99}$Tc and its signal changes in living tissues (23, 25). This unique application of Fourier Transform NMR spectroscopy was used to demonstrate the absence of Cardiolite’s binding to intracellular molecules in heart tissue (31).

Davison and Jones were also two of the founding speakers at the first International Symposium on Technetium in Chemistry and Nuclear Medicine held at the University of Padua, Italy, in 1982. The Italian venue was chosen to honour the discovery of technetium by the Physicist Emilio Segrè (Perrier & Segrè 1937). This meeting has been held every four years since, although the topics have expanded to include all radio tracer metals in medicine. Davison’s enthusiasm and support for this conference, dedicated to the understanding and techniques of ‘hot atom’ chemistry for applications in molecular imaging and biology, continued for many years. He supported a number of students to present the work on new technetium compounds and their interactions with biological systems. Notable new compounds were made and presented on tetra- and tri-thiolate ligands with technetium by Nadine deVries (PhD 1988, MIT), Nathan Bryson (PhD 1988, MIT) and Jessica Cook (PhD 1995, MIT) (24, 27, 29).
In an imaginative challenge, stemming from a continued interest in nuclear medicine applications of chemistry, Davison (working with post-doctoral fellow John Valliant PhD) proposed the synthetic target of a technetium complex containing six boron-cage-substituted isocyanide ligands. Such a multi-purpose molecule could be imaged using a gamma camera due to the properties of technetium, and it would also carry a substantial payload of boron to the tumour for destruction by boron neutron capture therapy (33, 34). Additional projects with post-doctoral fellows Terry Nicholson PhD, Matthias Friebe PhD and Ashfaq Mahmood PhD developed additional projects targeted to melanoma or neurological diseases such as Parkinson’s.

**ALAN DAVISON THE TEACHER AND MENTOR**

Over the years Alan Davison served as thesis advisor to more than 50 graduate students, 24 of whom were focused on technetium chemistry, the field for which he is best known. Numerous graduate students and post-doctoral fellows from his laboratory have become leaders in nuclear medicine and continue to make valuable contributions to molecular imaging. As important to Davison as his research accomplishments were, his many activities included mentoring and nurturing the growth of students, generously not limiting his attentions to those in the chemistry department. Alan Davison (along with Alun Jones) were longstanding members of Boston’s ‘Welsh’ club where they would share camaraderie with fellow expatriates along with practice of their ancient Welsh language skills at monthly meetings.

He loved the sport of rugby, played it and served as the coach to the MIT rugby club team for several years as well. One rite of passage for all members of Davison’s research group was the annual birthday celebration. By some random coincidence, although Davison and Jones were separated by five years in age, their birthdays only differed by three days. Davison was born on 24 March and Jones was born on 21 March. The joint birthday celebration was a daylong event that began with ‘a’ Welsh beer before noon and sometimes lasted into the wee hours of the night. A lot of great memories were had (and forgotten) by many group members over the 30-year collaboration.

Alan Davison was blessed with an incredible memory, which was evident in his lectures when he would effortlessly relay subtitles from the chemical literature and correlate them with real world experiences. His memory was kept sharp by his unique filing system that consumed his entire office with 2–3-foot stacks of papers and publications in process. He used to say ‘I am sorry for the mess but I know exactly where everything is’, although to any visiting scholar or janitorial worker the office was ‘randomized’ chaos. Indeed, the office was off limits to custodial staff without supervision. Davison was once presented with a large silver cup adorned with the following inscription: ‘The office of minority education presents this award to Professor Alan Davison in recognition of his 14 years of outstanding support and dedication to project interphase.’ Project interphase is a scholar enrichment programme designed to ease the transition to MIT and to build community among new students. He kept this cup on display in his office for many years. Alan Davison’s mentorship had a profound effect on his many students and post-docs. His brilliance and chemical insight, matched with humour and compassion, were a precious gift to all his students.

Upon his retirement in 2005, the MIT Department of Chemistry established an endowed lectureship in his name, a reminder of his commitment to mentoring. Similarly providing an
enduring reminder of Davison’s contributions is the Davison Prize, awarded annually for the most outstanding MIT PhD thesis in inorganic chemistry. Recipients of this prize have gone on to outstanding careers in academia and chemical industry. During his research career Davison authored or co-authored more than 250 publications and was a co-inventor on nine patents; one of these, the Cardiolite patent, surpassed within three years the amount of royalty income of all previous patents from both Harvard and MIT.

**Alan Davison the person**

Alan Davison was a great story (and joke) teller, a talent he developed long before the Internet introduced the inclusion of pictures and video to this ancient genre. In fact, when Alan attended large chemistry meetings, he would regularly attract a following of younger chemists because of his reputation of telling entertaining and humorous stories and always finding the most fascinating or historical venues in a different city. Alan sired five children with his first wife Francis and, although spending 12–16-hour days during the week left most of that hard lifting to his wife, he much relished spending family time on the weekends. As his children grew older he began organizing events that brought the academic and biological families together, such as camping trips or sausage-making parties. In 1994 Alan married Lynne (Penney) Dowling and added her two children (Erin and Myles) to the family. In 2005 he retired from MIT and began to spend more time at his bayside home on Massachusetts’ Cape Cod. There, he finally had time to spend on several of his other interests, including gardening, cooking, fishing and planning exotic family vacations. Alan Davison died peacefully in North Falmouth, Massachusetts, after a long illness. He is survived by his wife of 21 years, Lynne Davison, and his children, Jackie Davison Kelly, Fiona Davison Blauvelt, Robert Davison, Rowena Davison Schommer, Ian Davison, Erin Dowling Luce and Myles Dowling, as well as 16 grandchildren and four great-grandchildren.

**Honours**

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<tr>
<td>1967–1969</td>
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<tr>
<td>1990</td>
<td>Honorary Fellowship, University College of Swansea, UK</td>
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<tr>
<td>1990</td>
<td>Herbert M. Stauffer Award for Outstanding Laboratory Paper (26)</td>
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<td>1993</td>
<td>Paul C. Aebersold Award for Outstanding Achievement in Basic Science Applied to Nuclear Medicine</td>
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<tr>
<td>1998</td>
<td>University of Padua Medal for Contributions in the Chemistry of Technetium and its Application to Medicine</td>
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<tr>
<td>1999</td>
<td>Ernest H. Swift Lectureship, California Institute of Technology</td>
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<td>2000</td>
<td>Fellow, the Royal Society</td>
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<td>2006</td>
<td>American Chemical Society Award for Chemical Invention</td>
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<td>2006</td>
<td>Jacob Heskel Award, Brandeis University Award Lectures in Biotechnology and Medicine</td>
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<td>2006</td>
<td>Wallace H. Carothers Award</td>
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<tr>
<td>2009</td>
<td>Georg Charles de Hevesy Nuclear Pioneer Award, the American Society of Nuclear Medicine</td>
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Photographs are provided with permission from his family and friends. Frontispiece portrait of Alan Davison, 2000 ©The Royal Society.

AUTHORS’ PROFILE

Malcolm L. H. Green

Malcolm L. H. Green BSc, PhD (Lond), MA (Cantab), MA (Oxon), FRS. Emeritus Professor of Inorganic Chemistry Department, Oxford University, Oxford. Malcolm Green was a graduate student with Sir Geoffrey Wilkinson FRS at the same time as Alan Davison and he and Alan remained close friends. He moved from Imperial College to Cambridge University and then after three years became a Fellow and Tutor at Balliol College, Oxford University. He later was awarded the Chair of Inorganic Chemistry until he retired in 2003. Since then he has been developing a method of covalent bond classification.

Christopher C. Cummins

Christopher C. Cummins PhD (1993, MIT), Henry Dreyfus Professor of Chemistry, Department of Chemistry, Massachusetts Institute of Technology, Cambridge MA, USA. Christopher Cummins was a graduate student in the Inorganic Chemistry programme at MIT and enjoyed learning from Professor Davison both informally and in the classroom. In 1993 he joined the MIT faculty to teach and conduct research activities in exploratory synthetic chemistry as Professor Davison’s colleague in the same Inorganic Chemistry programme. Cummins was promoted to professor in 1996, and in 2015 was named to hold the Henry Dreyfus chair, his current appointment.

James F. Kronauge

James F. Kronauge PhD (1987, MIT), Vice President of Chemistry, inviCRO LLC, Boston, MA, USA. James Kronauge was a graduate student with Professor Davison at MIT from 1983 to 1987, focused on the synthesis and characterization of new technetium compounds as myocardial imaging agents. After obtaining his doctorate degree in 1987 he was an instructor and assistant professor at Harvard Medical School and collaborated with Professor Davison for an additional 12 years. From 2000 to the present he has been working in industry in the molecular imaging and drug development fields in Boston.
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