RICHARD DICKINSON CHAMBERS
16 March 1935 — 18 April 2019
Richard (Dick) Chambers was one of the most creative and distinguished organofluorine chemists of his generation. He synthesized a range of perfluorinated heteroaromatic systems, including pentafluoropyridine and tetrafluoropyrimidine, by halogen exchange processes, and established their chemistry and associated reaction mechanisms. Notably, 'mirror image' negative Friedel–Crafts reactions led to perfluoroalkyl heteroaromatic derivatives that could be transformed into unusual valence bond isomers by irradiation. New ranges of stable, observable perfluorinated carbanions, alkenes and dienes were synthesized and their fundamental chemistry established. Dick was an excellent experimental scientist whose career was marked by his unique skill-set in being able to perform reactions at high pressure under vacuum, using γ-ray irradiation, photochemistry, continuous flow processes and a variety of fluorinating reagents. His research into the use of elemental fluorine gas, which established the key role of solvent in reaction control, established fluorine as a viable reagent for organic synthesis. Several of his new synthetic processes, including syntheses of perfluorocarbon iodides, highly fluorinated heteroaromatic derivatives and α-fluoro-β-ketoester systems, were adopted for scale-up by industry. But Dick was more than a talented and innovative scientist. He was also an outgoing and fun-loving man, who always made time to offer support, guidance and advice to all his colleagues, research group members and scores of scientific friends within the fluorine science community around the world. As a result, he forged strong personal bonds throughout his life and a legacy that has lasted through generations of chemists.

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Early Life and Interests

Dick was born in 1935 in the small mining village of West Stanley, Co. Durham, to Alfred and Elizabeth Chambers, the third of four children (figure 1). Over the war years, Dick attended Greenland Junior School, where the formidable Miss Skene was totally dedicated to enabling as many children as possible to pass the UK general 11-plus exam and gain entry to the grammar school, instead of ‘going down the mine’ at the age of 14, as the vast majority of boys born in the Durham area did at the time. Dick duly entered Stanley Grammar School in 1946 with great encouragement and support from his parents and community.

These early years were difficult; his mother was an invalid, he lost a brother to a childhood illness and, when his mother died, he thought he would have to give up his studies to help raise his young sister. His household chores included making the coal fire every morning, and memories of doing this on freezing cold North-East mornings were remembered many years later when he worked with an architect to design and build the new family home—no fireplace was included in the design and the central heating system was the best money could buy.

Science teaching at Stanley Grammar was inspirational, if rudimentary, and he was particularly excited to begin experiments in a real chemistry laboratory. Dick never had any doubt about wanting to be a chemist and the school laboratory enabled him to carry out much safer experiments than he was practising at home. His father’s job as a coal miner provided a ready supply of detonators and cordite, which he deployed with great enthusiasm to disrupt the neighbouring boy’s lead toy soldier collection and to make rockets out of old tin cans.

During his teenage years, Dick began to indulge in his lifelong interests in photography, cinema, tennis and, as for all boys in the Durham area, watching Sunderland AFC, a passion...
that he continued as a season ticket holder for over 50 years. Dick watched the performances of his team with typical stoicism, but he loved the club and the people he saw there each week. Later, his son Mark had no choice but to become a Sunderland supporter and, when Dick took Mark to his first match as a youngster, he told him that the experience would be character building and useful in later life. Watching the team lose regularly was always, however, a great day out and there was always a misty eye when Dick recalled Jim Montgomery’s double save in Sunderland’s victorious 1973 Cup Final appearance.

**Student days at Durham University**

With the financial support of a Durham County Council Exhibition award, Dick accepted an offer to study chemistry at University College (Castle), Durham University. While the distance from West Stanley to Durham is less than 10 miles, he thought that he was entering a new world, taking up rooms first in Lumley Castle as a fresher, then subsequently in Durham Castle for his final two years as an undergraduate. Three hot meals were served each day even though rationing was still in force, but ‘potatoes with mash’ was not an uncommon main course. Meeting students from a wide variety of backgrounds was tremendously enriching, and this period began a long association with University College Durham. Long hours in the undergraduate laboratory left little time for sports, although he took up squash as an undergraduate to represent Castle, and Dick studied hard to gain a first class degree. Only students with the highest degree classes were eligible for grants to fund PhD studies, with the other option being assigned National Service in the army, something that helped focus his mind considerably. The mechanistic approach to organic chemistry was just developing, which completely changed the way organic chemistry was taught and had a marked effect on Dick’s thinking about the subject. During his third year, Dick carried out his undergraduate research project in the laboratories of Professor Ken Musgrave, coincidentally another Stanley Grammar School alumnus, and was introduced to organofluorine chemistry for the first time. Subsequently Dick joined Ken’s research group and began his PhD studies in Durham in 1956, developing the first electrophilic oxidation of aromatic systems using peroxy-trifluoroacetic acid (1)* (scheme 1).

Facilities and equipment at Durham were, at best, limited and before any chemistry experiments could take place Dick constructed his own vacuum line using his newly acquired glass blowing techniques (figure 2) and a simple gas–liquid chromatography apparatus for analysis and separation of organic mixtures. In particular, vacuum line techniques and the ability to handle small quantities of toxic gases safely in the laboratory using techniques learned from Professor Geoffrey Coates, an organometallic chemist at Durham, were particularly valuable, enabling much subsequent fluoroalkene, fluoroaromatic and free radical chemistry to develop within Dick’s research group. Dick was happy to learn skills and techniques from everyone in the department and treated the technical staff with utmost respect as they transferred their practical expertise. As a junior chemist, he was lucky to avoid serious injury when a distillation experiment exploded on the bench directly in front of him because he was wearing safety spectacles, which was unusual at the time. Throughout his career he

* Numbers in this form refer to the bibliography at the end of the text.
considered the safety of his co-workers very seriously, particularly when handling toxic gases at high pressure.

Dick attended the first International Symposium on Fluorine Chemistry in 1959 at the University of Birmingham, UK, becoming immersed not just in the scientific advances in organofluorine chemistry worldwide, but also in developing the first of many long-standing and rewarding friendships with scientists across the globe. However, after meeting at a Castle
summer party, the most important event for Dick occurred in August 1959 when he married Anne Boyd, who had just qualified as a primary school teacher in Durham. Their honeymoon was spent sailing across the Atlantic followed by a trans-Canadian rail trip to Vancouver to Dick’s next academic position (figure 3).

**Postdoctoral research at the University of British Columbia, 1959–60**

Dick joined the group of Professor Howard Clark, later president of Dalhousie University, Canada, to study reactions of perfluoroalkyl-organometallic compounds. The position was funded by the US Navy with the aim of developing fluorocarbon derivatives of tin with possible application as anti-fouling agents for marine vessels. He prepared and characterized the first stable perfluoroalkyl derivatives of tin and boron. For example, UV irradiation of hexamethylditin led to trimethyl tin radicals, which upon reaction with trifluoromethyl iodide gave trifluoromethyltrimethyltin, one of the earliest uses of organo-tin radicals in chemical synthesis (2) (scheme 2).

Dick shared a laboratory with a fellow UK North-East native, Professor Neil Bartlett (FRS 1973), who was then an instructor at the University of British Columbia, and Dick was impressed by the methods Neil had developed to handle elemental fluorine gas. Watching Neil react platinum with fluorine to give platinum hexafluoride as part of his ground breaking programme on noble gas chemistry was particularly memorable, although the presence of the large cylinder of fluorine gas located between the bench and the exit of the laboratory was rather disconcerting and well recalled in later years when a fluorine laboratory was designed and built in Durham.

After a few months in Canada, Dick received an offer of a permanent lectureship in organic chemistry from Durham University and he was happy to return to his alma mater after only a one-year absence (figure 4).
On his appointment at Durham, Dick began a collaborative research programme in organofluorine chemistry with Professor Ken Musgrave, just appointed as chair of organic chemistry. The organic chemistry teaching section consisted of just Ken and Dick, with Ken teaching the first year syllabus and Dick covering all the other organic chemistry courses studied by the second and third year cohorts as well as supervising the undergraduate laboratory classes. He devoted himself to his job and worked all hours. He would always manage to be home for dinner, but would often disappear to his study afterwards to continue...
working late into the night. He enjoyed teaching and put a huge effort into preparing for his many undergraduate and scientific conference lectures. Making slides, pre-PowerPoint, was an intensely laborious process, and his home study was always littered with colourful paper cut-outs and sticky labels as he prepared his photo-ready lecture material.

As a miner’s son, Dick was viewed initially with suspicion by some academic members of the department who held entrenched right wing political opinions. To counter this, Dick subscribed to the *New Statesman*, a left wing weekly publication, and secretly delighted in recounting the editorial polemics in the staff coffee room and watching the inevitable explosion of indignation.

The university opened a new chemistry building in 1960 and a number of new staff were employed, including, among others, Professors Jim Feast (FRS 1996) and Ken Wade (FRS 1989), in line with the general expansion of UK universities in the early 1960s.

Fluorine has a unique relationship with hydrogen in that the hydrogen atoms in an organic molecule can be replaced individually or completely by fluorine atoms. Since compounds containing carbon–fluorine bonds, with minor exceptions, do not occur in nature, organofluorine chemistry is entirely ‘man-made’ and, throughout his career, this offered Dick opportunities to synthesize unique classes of organic systems and explore their chemistry. Much of Dick’s work in synthesis over the course of his career was mechanism-led because it was an exciting period at the beginning of his career, when ‘lasso chemistry’ was ending and mechanistic understanding of reactivity of organic compounds was unfolding. Consequently, integration of the chemistry of organofluorine compounds into more general mechanistic models was a major task for workers in the field and one which Dick fully embraced. However, curiosity and serendipity are important in organofluorine chemistry, in particular, because it is usually difficult to anticipate much of the chemistry of such novel systems.

Not surprisingly, Dick’s interest in organometallic derivatives of fluorocarbons first initiated in Vancouver was continued in his first projects as a new lecturer in Durham. The first pentafluorophenyl-tin, -boron and -aluminium derivatives were synthesized and polymerization of propene was found to be catalysed by pentafluorophenylaluminium dibromide, developed with PhD student Jack Cunningham (later Lord Cunningham of Felling) (5, 6) (scheme 3). At this early stage of his career, Dick was mindful of not being type-cast as an inorganic chemist because his interests were primarily in developing organic processes. Consequently, he quickly turned his attention to developing the chemistry of non-metallic derivatives of fluorocarbons and, subsequently, Professor Gordon Stone (FRS 1976) made great strides in further developing the chemistry of pentafluorophenyl derivatives of the elements in the UK.
Following his research in Vancouver, Dick was interested in expanding the chemistry of perfluoroalkyl iodides, but these compounds were not commercially available in the UK. Consequently, a route involving addition of iodine monofluoride, derived from reaction of iodine and iodine pentafluoride, to tetrafluoroethylene to give pentafluoroethyl iodide was developed (3) using all the vacuum line techniques learned in Vancouver and from the Coates group in Durham (scheme 4). UK chemicals giant ICI was given the opportunity to patent this process, but declined. Subsequently, manufacturing-capacity plants were built by DuPont (USA), Attochem (France) and Asahi Glass (Japan) to supply pentafluoroiodoethane to the developing high performance surfactant industry, which became a billion dollar annual business for many years. Dick always regarded this opportunity as ‘the one that got away’!

In line with Dick’s desire to develop the organic chemistry of perfluorinated organic systems, the synthesis and chemistry of perfluoroheteroaromatic derivatives began in the early 1960s and continued as a research theme throughout his career. While the parent compound of this class, pentafluoropyridine, had been prepared at the University of Manchester by Professor Bob Haszeldine (FRS 1968), the preparative route reported was difficult. Dick developed a more accessible two-stage route by first preparing pentachloropyridine by exhaustive chlorination of pyridine using chlorine gas and phosphorus pentachloride in high temperature reactions under pressure (4). Halogen exchange processes involving reaction of pentachloropyridine with potassium fluoride in a solvent led to 2,4,6-trifluoro-3,5-dichloropyridine, which subsequently was used as a substrate by Dow Agrochemicals for the manufacture of a major herbicide, Starane, which has been on the market now for several decades. However, pentafluoropyridine could be synthesized in high pressure reactions. Pentachloropyridine and dry potassium fluoride were added as solids to an autoclave, a stainless steel reaction vessel colloquially known by the research students as a ‘bomb’, and after heating together at temperatures typically over 450°C, volatile pentafluoropyridine can be recovered from the hot autoclave in the vapour phase by vacuum line techniques (scheme 5). Using analogous processes, a range of perfluorinated heteroaromatic systems including tetrafluoropyrimidine and perfluoroquinoline were synthesized (13) and ironically, in most cases, the most difficult step of the synthetic strategies was the synthesis of the perchlorinated precursor. With useful quantities of pentafluoropyridine and related perfluoroheteroaromatic systems now available, Dick began to explore the chemistry of this new class of organic compounds and his group established reactivity profiles, reaction mechanisms, regioselectivity of nucleophilic aromatic substitution processes and reaction kinetics of these novel systems (8) (scheme 5). In particular, the 1960s saw great strides in perfluoroheteroaromatic chemistry, with other research groups, particularly within the
agrochemical industry and at the University of Manchester, contributing very significantly to the field.

The principles behind the regioselectivity of nucleophilic aromatic substitution of perfluorinated aromatic and heteroaromatic substrates had been the source of much debate, but a series of kinetics experiments in collaboration with Professor Lyn Williams, a longtime colleague at Durham, allowed Dick to establish that nucleophilic aromatic substitution of fluorine occurs at positions that maximize the number of activating fluorine atoms relative to the site of attack (10, 11). Fluorine atoms para to the site of nucleophilic attack are slightly deactivating, while fluorine meta are activating and fluorine ortho to the site of nucleophilic attack are very activating due to polar effects on the substrate. Consequently, nucleophilic substitution of pentafluoropyridine occurs exclusively at the 4-position, in which the number of activating fluorine atoms (2 ortho and 2 meta) is maximized and deactivating fluorine atoms are minimized (no para fluorine). These simple rules (Scheme 5) were used to explain the reactivity profiles of many newly synthesized perfluoroheteroaromatic systems prepared at Durham using the high temperature solventless two-stage perchlorination/halogen exchange processes and reported in a series of over 50 research papers over 40 years.

Dick showed that a particularly interesting nucleophile could be generated by reaction of fluoride ion with hexafluoropropene, and the perfluoro-isopropyl carbanions formed reacted with pentafluoropyridine to give perfluoro-isopropylated products (7). This ‘mirror image chemistry’ was analogous to the more generally known protonation of alkenes to give
carbocations that react with aromatic species to form alkylation products, termed Friedel–Crafts processes. Such ‘mirror image’ fluoride ion induced perfluoroalkylation reactions became known as ‘negative Friedel–Crafts’ reactions. Many nucleophilic substitution and perfluoroalkylation reactions were carried out by the Chambers’ group, and synthesis of macrocycles from perfluoro-4-iso-propylpyridine is presented here (21) to illustrate the chemistry that subsequently developed from the initial synthesis of pentafluoropyridine in 1960 (scheme 6).

Negative Friedel–Crafts chemistry allowed the preparation of various substrates that were ideal for studying photochemical rearrangements of diazines and the isolation of very unusual valence bond isomers (9) (scheme 7). Disubstituted pyridazine derivative 1 dramatically rearranged to the corresponding pyrazine derivative 2 upon irradiation, and Dick showed that the reaction proceeded via the relatively stable Dewar-type isomers 3 and 4. Similarly, photolysis of pentasubstituted pyridine derivative 5 first gave Dewar-type isomer 6 then azaprismane 7, both of which were isolated (12). The existence of valence bond isomers of benzene and pyridine still comes as rather a shock to undergraduates who see the aromatic isomers of benzene and pyridine as being the only isomers ‘possible’.

At the invitation of Professor George Olah (Nobel Laureate for Chemistry, 1994; ForMemRS 1997), Dick took up a position of visiting lecturer at Case Western Reserve University in September 1966 with the help of a Fulbright Fellowship. With two small children, Mark and Louise (figure 5), life was not particularly easy on the salary of a lecturer in the UK and the contrast with lifestyles in 1960s America was dramatic and tempting at the
time. So the sabbatical year was taken partly with a view to consider moving to the USA, but, as is often the case, home ties proved too strong. When Dick and his family first arrived in Cleveland, they were met at the airport by a member of the English faculty whom they had not met before. Their new hosts announced that they had cancelled the hotel reservation and instead made room for the jet-lagged family in their own home, and they lent Dick a car for the week to help get the family settled in. Dick and Anne were stunned by the warmth of the welcome and enthusiastically adopted that model when back in the UK, hosting visitors and events on a regular basis at the family home.

Scientifically, Dick’s year in Cleveland was highly influential and, as well as preparing new classes of relatively stable carbocations in the Olah laboratories, his graduate lecture course (20 lectures) on organofluorine chemistry was, at Professor Olah’s suggestion, expanded into a book. Dick’s monograph, *Fluorine in organic chemistry*, was published in 1973 (8) with a second, fully revised, edition appearing in 2004. His important book had a strong mechanistic emphasis and proved extremely valuable to the community, as well as helping to integrate the field of fluorine chemistry into ‘mainstream’ organic chemistry.

The international nature of science was a great source of joy to Dick throughout his career and he loved the time spent living in Canada and the US and, latterly, his short spells in Egypt and Paris. He travelled widely, attending many international conferences on fluorine chemistry over the course of his career and visiting the USA, Japan, China, Russia and across Europe delivering lectures and developing his links with the scientific fluorine chemistry community, through both scientific discussions and, at the end of the scheduled lecture programmes, more social interactions (figure 6).

In particular, Dick had many scientific friends in the former Communist bloc and travelled to the USSR, Czechoslovakia and the Ukraine to present lectures both during the Cold War
and in more recent times. Following each of his trips to the former-USSR in the 1970s he was visited by ‘a suit from London’ to discuss his experiences of academic life, laboratory provision and life behind the Iron Curtain, interviews that he did not appreciate but took some mischievous pleasure from. His visitor would place his briefcase upon Dick’s office desk and continue to adjust its position as Dick moved around while he spoke. Dick soon cottoned on to this clumsy recording attempt and started walking around the room, covering his mouth and speaking at the window to make life difficult for his visitor. Both participants looked at each other with gentle ‘I know what you are doing’ smiles.

Following the end of the Cold War, Dick organized a visit from a delegation of Russian organofluorine chemists to Durham in 1993 and this trip was very much enjoyed by both visitors and hosts. A conference dinner was held at a local restaurant, for which Dick had negotiated a fixed price deal. However, everyone began ordering a-la-carte and the evening rapidly swung out of control in a tidal wave of bonhomie, multiple toasts and huge conviviality. Dick’s hangover began early when the bill arrived. Part of the great friendships that developed were because Dick went the extra mile to support and champion people he believed in. He helped a co-worker to leave the Soviet Union, and at the first conference that he was able to attend in the US, Dick introduced the young scientist to the audience and informed them that he was seeking a job. Settling in the USA changed this person’s life and Dick was quietly very proud of helping in such a way.
The ‘mirror image’ relationship between hydrocarbons and perfluorocarbons was further extended by the direct observation of perfluorocarbanion systems by $^{19}$F nuclear magnetic resonance (NMR) spectroscopy (14), contrasting the classic work by Professor Olah on the observation of stable carbocations (scheme 8). Addition of fluoride ion to perfluoroalkenes gave the corresponding perfluorocarbanions, mirroring the protonation of alkenes in hydrocarbon systems. Addition of fluoride to perfluoro-iso-butene to generate perfluoro-tert-butyl anion was particularly hazardous because the alkene substrate is very highly toxic. Co-workers Andy Bailiff and Tom Holmes prepared the perfluorocarbanion solution on a very small scale and recorded the highly sought NMR spectra over a very quiet weekend in the department while wearing breathing apparatus.

Dick was appointed to a personal chair in 1976 and to one of the established chairs of chemistry in 1981, then to chairmanship of the department (1983–86) when, for a short time, he was the only professor remaining in the department. This was a difficult time for the chemistry department at Durham because many of the essential analytical facilities (NMR, mass spectrometry) had become antiquated together, but collaboration between the department and university ensured excellent provision of new analytical equipment. Dick was unafraid of making his views known and, while this did not always help him when dealing with authority or competitors, he always felt that it was better if everyone’s viewpoint was out in the open so that progress could be made. For example, if a student didn’t deserve a 2 : 1, he was quite happy to explain to an aggrieved parent why the lesser degree was the only grade that was appropriate. A series of excellent new appointments within the department in the 1980s, including Professor David Parker (FRS 2002), Professor Judith Howard (FRS 2002),
Professor Jeremy Hutson (FRS 2010) and Professor Jas Pal Badyal (FRS 2016), saw chemistry at Durham go from strength to strength over the next few decades.

The synthesis and reactions of a new family of perfluorinated dienes became a research theme from the mid-1980s (scheme 9). De-fluorination of perfluoroalkenes using sodium amalgam gave perfluorodienes that could react with a variety of difunctional nucleophiles to give access to perfluoroheterocyclic systems (15) and unusual pentakis(trifluoromethyl) cyclopentadienyl salts (18), another important member of the perfluorinated carbanion family.

The 1980s and 1990s saw Dick’s group become engaged in developing free radical chemistry of fluoroalkenes following significant funding from the US Air Force aimed at developing new high performance perfluoropolyether lubricant fluids (scheme 10). The polarity of radicals was well recognized within the organofluorine community, and Dick took advantage of using γ-ray irradiation or peroxide chemical initiators to generate carbon-centred free radicals by cleavage of carbon–hydrogen bonds in a wide range of substrates, including alkanes, ethers, amines and alcohols. The nucleophilic radicals, stabilized by adjacent
heteroatoms where appropriate, react very efficiently with electrophilic perfluoroalkenes to generate electrophilic radical intermediates that, in turn, abstract hydrogen atoms from the electron rich hydrocarbon substrates. Such free radical chain reactions led to a number of new polyfluorohydrocarbons (20) which could be elaborated into new polyfluoro-alkenes and -dienes, continuing the theme of exploring the chemistry of highly fluorinated unsaturated systems begun in Durham. It was a source of much regret to Dick that the head-of-department and other duties meant that much research carried out by his group on this topic was unpublished owing to time constraints, and thus rests within the individual PhD theses of the group members. Some of the polyfluoroalkylated polyethers were used by ICI as foam insulators in refrigerators and, to complete the project, were reacted with fluorine gas to give the target perfluoropolyethers (19).

A large section of the rich portfolio of Dick's research over the decades was enabled by government funding of first class degree students who, inspired by Dick’s teaching, opted to remain in the chemistry department at Durham for their doctorate studies. He also attracted students from other UK universities and from industry, and Dick was patient with and understanding of the diverse backgrounds of his student network and their various needs. Collaboration with industry was a significant feature of Dick’s research for his entire career. His research was funded by many UK and international organizations, including ICI (UK), Dow (USA), Ausimont (Italy), Asahi Glass (Japan) and USAF (USA) among many others, which compensated for little funding from the UK research councils. Dick’s unique knowledge and skill bases in organofluorine chemistry were very important to industry and he consulted, at various times, for ICI, Monsanto, 3M, Central Glass and Asahi Glass.

In the 1990s, British Nuclear Fuels Ltd (BNFL) decided to expand its business areas by developing its non-nuclear expertise. As a producer of around 1500 tonnes of fluorine gas per annum, primarily used for the preparation of uranium hexafluoride, a new subsidiary company was formed, F2 Chemicals Ltd, that aimed to utilize fluorine gas for fine chemical
Scheme 11. Selective direct fluorination using fluorine gas.

manufacture. With no research background in the field, in 1992 BNFL invited Dick to set up a research team of three employees seconded to the university. Dr John Hutchinson, one of Dick’s first PhD students in the 1960s, who first synthesized pentafluoropyridine using the two-stage chlorination/halogen exchange process, returned to the group to head up the F2 Chemicals unit. This collaboration led to the publication of a series of papers that helped change the perception that fluorine gas, for so long considered too reactive and uncontrollable, could be used for selective fluorination reactions. The key breakthrough was the simple idea that the electrophilic reactions of fluorine could be enhanced in acidic reaction media such as formic acid or solvents of high relative permittivity such as acetonitrile (16).

Selective fluorination reactions of \( \beta \)-ketoester derivatives (17) were established and scaled up by F2 Chemicals for customers in the pharmaceutical industry. The manufacture of the globally available antifungal medicine voriconazole (V-Fend, Pfizer) involves the use of direct fluorination of a \( \beta \)-ketoester developed at Durham for the formation of a key fluoropyrimidine building block. During the collaboration with F2 Chemicals, Dick became interested in continuous flow processes for fluorine gas and a multi-channel system with many reactors in parallel was designed, constructed and used for large scale synthesis (22).

Particularly memorable was the period in summer 1994 just before the International Fluorine Symposium that was held in Yokohama, Japan. Dick wanted to present ‘a big splash’ on direct fluorination to help raise the profile of F2 Chemicals. Consequently, his research group tried many different experiments to demonstrate the versatility of fluorine gas as a reagent in a very short time period (scheme 11). This culminated in a new fluorination reaction being carried out in the morning, followed by drafting and filing the relevant patent in the afternoon, an exciting period that carried on for several weeks before the group got on the plane to Japan for Dick to report these new discoveries ‘hot off the press’. The conference went well, Dick was subsequently appointed as a non-executive director of F2 Chemicals, and the intellectual property rights portfolio helped in the ultimate sale of the company to an industry consortium of Asahi Glass and Mitsubishi Chemicals.

By Dick’s formal retirement in 2000, he had supervised 96 PhD students to completion and had hosted many postdoctoral co-workers and industry visitors from overseas, including Japan, Europe and the USA, within his laboratories in Durham. Over the years the synthetic capabilities of Dick’s research group expanded to handling gases by vacuum line techniques, glass Carius tubes, autoclaves for high pressure reactions, \( \gamma \)-ray irradiation, photochemistry and handling a range of fluorinating agents such as cobalt trifluoride, sulfur tetrafluoride and fluorine —a unique skill-set worldwide.

Dick was always very keen to recognize the efforts of his research co-workers, technical staff and colleagues who helped him publish over 300 papers, patents, book chapters and reviews. The first slide of all his lectures at conferences, academic and industrial locations, all too numerous to remember, contained the names of his research co-workers. He viewed
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this slide as the most important of the whole presentation, so he did this at the start of all his presentations in case time ran out—which it invariably did. He was a great ambassador for Durham and the region, always telling strangers about how wonderful Durham is and encouraging everyone to visit. Every international lecture also began with a photograph of Durham Cathedral and an open invitation to anyone present to visit Durham and stay at his home. Many scientific friends and colleagues took up this open offer and Dick and Anne always loved welcoming new people into the house. On one occasion, he received an unexpected phone call from Darlington station, 20 miles south of Durham, late one evening. It was from a couple of undergraduates from the USA who had been given Dick’s phone number by their lecturer, one of Dick’s international friends. An hour later they were enjoying a swiftly pulled together meal and a bed for the night, before setting off for Edinburgh the following morning. This open hospitality helped build an incredibly varied network of friends across the world and many memorable evenings in Durham. Anne’s Christmas card list was enormous and she had to start the process of writing cards in November each year, taking multiple trips to the Post Office to send cards to well over a dozen countries.

Anne was a vital part of the relationship building with and hospitality to all nationalities of scientific visitors to Durham and supported Dick in his scientific work. She built strong family connections with many of Dick’s colleagues around the world, and the couple used to spend two weeks in Florida each year visiting Professor Paul Tarrant (University of Florida) and his family and playing golf with Professor Don Burton (University of Iowa) and his wife Marge. Anne accompanied Dick on many trips abroad to attend various conferences and lecture tours, and was a source of many stories at subsequent group gatherings. On a visit to Japan, they were hosted by the president of a major chemical company for dinner in a private dining room at its headquarters building in Tokyo. Encountering a mechanical Japanese toilet for the first time during a mid-meal break, Dick’s curiosity got the better of him and, after he had pressed a button at random, a large jet of water pinned him to the wall. He returned to the table dripping wet. Their hosts were, of course, too polite to comment, but Anne very much enjoyed retelling this story, fighting back the happy tears on each occasion.

Dick’s scientific contributions to the field of organofluorine chemistry over his career was recognized by his peers and it gave him immense personal satisfaction to be elected FRS in 1997, an event celebrated by all departmental academic, technical and administrative staff with a wine reception that went on well into the evening. Similarly, recognition by the world fluorine chemistry community came with the award of the highly prestigious Prix Moissan, an award made once every three years by the Maison de la Chimie in Paris and considered the premier award in the field. Dick was visibly moved by this honour, which he received at the International Symposium on Fluorine Chemistry held in Shanghai in 2004. The presentation was made at the conference dinner held below the Pearl Tower in Shanghai. The event was well remembered for the vast quantities of excellent and interesting food, but also for the brisk trade in ‘Rolex’ watches by the hawkers outside with many conference delegates. Dick managed to haggle three for 100 yuan (£5).

SUPERVISOR AND MENTOR

Dick was very close to his research students and their scientific efforts, motivating them with a wealth of imaginative ideas, instilling his passion and commitment to science. He listened
to their ideas, encouraged and advised, and, while he had his own strong opinions on the
direction their investigations should go, he encouraged his students to pursue their own ideas
and inspired them to expand their scientific explorations. On some occasions, however, Dick’s
advice would be what he felt the student really needed to be told. This ‘tough love’ approach
was based on his firm belief that being honest with people was the best way to help them be
honest with themselves.

Dick had a warm, friendly and informal approach and his frequent visits to his research
labs would begin with a cheerful ‘How’s things?’ or ‘How’s tricks?’ He had a good sense
of humour and loved to gently tease people, as well as enjoying being teased himself. His
morning greeting led to him being given the nickname ‘Tricky Dicky’, which caused him
much amusement. But when it came to a student’s attitude to the quality of their science, he
made no allowances for facetiousness. He was definitely not amused by the epigraph one
student wrote in his PhD thesis (translated from the Latin) ‘Never mind the quality, feel
the width’—a reflection of a ‘handle-turning’ rather than innovative approach to research,
contrary to Dick’s advice. After a very gruelling viva with his external examiner, the student
finally appreciated the need to listen to Dick’s words.

Dick absolutely loved having conversations with his students on a variety of topics. As
he got to know the students better, he also very much enjoyed hearing about their non-
scientific lives and sometimes their experiences really appealed to his mischievous sense of
humour. He enjoyed recalling a postgraduate student in his group who used to park her untaxed
and uninsured Citroën (which also had scorch marks on the bonnet due to an earlier engine
fire, and differing number plates on the front and rear) in the police station courtyard when
going into Durham. She explained that finding a parking space was very difficult in Durham
but there was always space in the police courtyard—a solution that Dick couldn’t help but
admire.

Dick often made space in his group for people whose background he recognized and
empathized with. Sometimes these gambles on people worked out and sometimes they didn’t,
but he was committed to giving everyone the opportunity to achieve their potential, echoing
his own experiences of the opportunities presented by attending grammar school in his
childhood. Indeed, Dick’s research group included young scientists from all over the world
and he very much enjoyed working with the postgraduate 18–24 year age group. He was
always entertained by the annual group outings to either Hadrian’s Wall, the Farne Islands
or the Lake District, which always ended in an impromptu game of football. Each year,
Dick and Anne hosted a research group dinner at home, which helped knit together the
team spirit in the lab and resulted in social ties that lasted for many years. These events
always involved late nights with wide ranging conversation. Students all over the world have
voracious appetites and Anne went to night school pottery classes to fabricate cookware large
enough to make the huge quantities of very much appreciated food. Anne also involved
herself in other aspects of university life, for example running the university play group,
whose members knew Dick as ‘Mrs Chambers’ husband’, which, he joked, ‘put him in his
place!’

Dick placed great emphasis on developing what are now termed transferable skills and
he took many hours to go over a group member’s monthly reports, first year transfer
reports and theses, discussing not only the scientific aspects but also how to construct an
argument and communicate using precise language. Group meetings were held regularly,
with all group members presenting the results of their experiments every fortnight. Everyone
took part; even Professor Neil Bartlett, who spent two sabbatical periods in Durham in the late 1990s carrying out new fluorination reactions using nickel fluorides, could be seen writing his presentation slides at the last minute along with the rest of the group. Dick realized very early on the growing importance of presentation skills, and was acutely aware that the impact of his students’ results was determined as much by the way they were delivered as by the quality of the science itself. For this reason, in the 1980s he embarked on videoing his students when they were rehearsing and coaching them through their performances. He was aware that this innovative approach could be somewhat intimidating, if not even a little brutal, but there was no ignoring the playback!

The wide range of technical, intellectual and chemical skills developed in Dick’s group influenced many colleagues in both academia and industry over the years. Indeed, many scientists who stayed at Durham or gave lectures in the department became ‘fluorinated’ to some degree, to the benefit of their subsequent research programmes.

In the summer of 2000 it gave Dick great pleasure to welcome over 700 delegates from 22 countries to the sixteenth International Symposium in Fluorine Chemistry, which he hosted in Durham. Many of his scientific colleagues and friends travelled from all over the world, including four delegates from the Ukraine who drove overland to Durham. The symposium banquet was held in Durham Castle Great Hall, from which Dick could see the window of the

Figure 7. Dick and Anne on a walking holiday in the Alps. (Online version in colour.)
room he occupied as an undergraduate—a fitting end to the journey taken on his formal career, which was recognized by a standing ovation from all present.

**POST RETIREMENT**

Dick continued as an emeritus professor of chemistry in the department for several years after his formal retirement and he enjoyed attending student presentations and discussions as much as always. He completed a second revised edition of his book (8), and his long association with the university was recognized by the award of the Chancellor’s Medal in 2008.

Unfortunately, Dick’s retirement was not as happy as we would have wished for him. His daughter Louise died and, subsequently, Anne passed away, leaving a lasting gap in what had been a perfect partnership (figure 7). However, Dick’s family remained a source of consolation, great pride and inspiration in the last period of his life. Dick died following complications of Parkinson’s disease in April 2019. He is survived by his son, Mark, and his beloved grandchildren, Dan, Ben, Alexa and Jack. I last talked to Dick in his care home in Durham just three weeks before he died and his final piece of advice to me, following many years of counsel, encouragement and help, was: ‘Graham, if there is anything you really want to do in life, just get on and do it.’ Dick was fortunate and content to have done all that he wanted to do.

**HONOURS AND AWARDS**

1966–67 Fulbright Fellow, Case Western Reserve University, Cleveland, USA
1988 Exxon Lecturer, USA
1988–89 Sir Derman Christopherson Research Fellow, Durham University, UK
1991 American Chemical Society Award for Creative Research in Fluorine Chemistry
1995 Visiting Professor, University of Paris, France
1997 Fellow, the Royal Society
1999 Inaugural Tarrant Visiting Professor, University of Florida, Gainesville, USA
2002 Inaugural Great Lakes Lecturer, University of Purdue, Illinois, USA
2003 Prix Moissan, Maison de la Chimie, Paris

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Richard Dickinson Chambers

AUTHOR PROFILE

Graham Sandford

Graham Sandford is Professor of Organofluorine Chemistry at Durham University, UK. He completed his PhD in organofluorine chemistry at Durham in 1991 under the supervision of Professor R. D. Chambers. After a period as a postdoctoral research fellow in the laboratories of Nobel Laureate Professor George Olah at the University of Southern California in Los Angeles, he transferred back to Durham. Following postdoctoral support from F2 Chemicals Ltd, he was awarded a Royal Society University Research Fellowship (1996), collaborating with Dick Chambers with a view to continuing the Fluorine group’s research activities following Dick’s formal retirement in 2000. Subsequently, GS was appointed lecturer at Durham in 2001, senior lecturer in 2004 and professor in 2008, and was deputy head of the Science Faculty at Durham from 2012 to 2015. His research interests were very much influenced by his early research with Dick Chambers and lie in the broad field of organofluorine chemistry.

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