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Elected FRS 1978

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Roger Cowley was one of the leading solid-state physicists of his generation. He was a highly versatile scientist who made important contributions to the understanding of the motion of atoms in solids and liquids, of the mechanisms of structural phase transitions, and of a range of magnetic phenomena, especially in systems with quenched disorder. Adept at both experiment and theory, he had the rare gift of being able to see through layers of complexity that often cloud real-world materials and capture the essence of their behaviour in simple models. His style was instinctively collaborative so he often worked together with some of the other leading people in his field, both nationally and internationally. His collaborative style also meant that he was frequently called on to serve in administrative roles. He was head of department at the University of Edinburgh for seven years and Chairman of Physics at Oxford for eight years. He played a large role in the administration of Oxford as a whole. Many of his graduate students went on to distinguished careers of their own, both within Britain and abroad.

EARLY YEARS

Roger Arthur Cowley was born on 24 February 1939 in Woodford Green, Essex, now part of Greater London. His parents came from Leighton Buzzard, Bedfordshire. His father, Cecil Arthur Cowley, was an estate surveyor and his mother, Mildred Sarah (née Nash), was from a farming family. He remembered spending time with his parents in Epping Forest in his early years. During the war his family returned to Leighton Buzzard for several years, where his

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http://dx.doi.org/10.1098/rsbm.2017.0011 139 Published by the Royal Society
parents would take him for bicycle rides into the countryside and Ivinghoe Beacon was a favourite spot. This started a lifelong enjoyment of bicycles and the great outdoors.

The family moved to Shenfield and then Gidea Park, within easy reach of London and its Science Museum, which Roger and his mother would visit often. He was 10 years old when his only sibling, Marion, was born. The following year, he won a scholarship to Brentwood School, where he was educated until 1957. He enjoyed playing rugby and cricket with the school teams. As a teenager, Roger also enjoyed spending school holidays with friends on cycling tours, staying at youth hostels in rural areas such as North Wales or the Lake District.

It was his chemistry teacher at Brentwood who persuaded him to try for Trinity Hall, Cambridge, and prepared him for the entrance examination. In 1957, Roger went up as a Scholar to read Natural Philosophy. He continued to play rugby but also enjoyed the summer sports of tennis, and bowls and croquet on the college lawns. During vacations he would spend time with friends walking in the mountains of Scotland and Wales.

**Graduate education**

Roger graduated in 1960 with a First Class degree in Physics. He decided to stay in Cambridge to carry out research for a PhD under the supervision of Bill Cochran. Roger’s fellow student Stuart Pawley comments:

As a research student starting my second year, I, along with Issai Lefkowitz, greeted the new recruit and gave him the boss’s recent long article and asked for an explanation. We did not get it, though in a way we did as Roger rewrote the article in quantum mechanical terms and then Bill and Roger together published it in *Handbuch der Physik* (5)*.

Bill was a pioneer in the study of atomic vibrations in crystalline materials. He had made the bold prediction that a structural phase transition in a solid could, in some cases, be associated with the existence of a ‘soft mode’ – a pattern of atomic vibrations whose frequencies fall with decreasing temperature until, at the point of instability, that displacement pattern freezes in to yield a new crystalline structure. Particularly dramatic behaviour was predicted for ferroelectrics where the structural transition was characterized by a divergence of the dielectric constant.

In order to test this idea experimentally, in 1961 Roger crossed the Atlantic to carry out a year’s research at the Atomic Energy of Canada Limited (AECL) laboratories in Chalk River, Ontario, Canada, a period that excited him so much that he knew he wanted to continue in research after writing up his thesis. In the mid 1950s, the group leader at AECL, Bertram N. Brockhouse, had invented a new kind of neutron spectrometer, namely the neutron triple axis spectrometer, which enabled the study of vibrational and magnetic excitations in solids and liquids as functions of both energy and momentum. In 1994, Brockhouse received the Nobel Prize for this invention and the pioneering research that he undertook with it. In 1960, Bill Cochran had been a visitor at AECL working with Brockhouse. They had mapped out the lattice vibrational spectra – that is, the phonon dispersion relations in an alkali halide material, sodium iodide – and they had fitted their measurements to a specific model known as the ‘shell model’. Roger extended these measurements to other alkali halides and, importantly, in

* Numbers in this form refer to the bibliography at the end of the text.
collaboration with Brockhouse, Cochran and A. D. B. (Dave) Woods, introduced significant improvements to the shell model. This mixture of precise experiments and sophisticated theoretical analysis would characterize Roger’s career from the beginning to its very end.

The most important work which Roger carried out for his thesis was testing the soft mode concept proposed by Cochran. This research focused on the phase transitions exhibited by materials with the perovskite structure, such as SrTiO₃. This class of materials was already attracting interest because of the perceived practical importance of their phase transitions into ferroelectric phases and the associated dielectric behaviour. The soft mode in this case was one in which displacements in adjacent cells were in phase. Roger was able to show that there was a transverse optic mode whose frequency squared decreased linearly with temperature, precisely mirroring the behaviour of the inverse dielectric constant and thus confirming Cochran’s proposal (1).

In tandem with this experimental work, Roger set out to develop the underlying theoretical framework. Vibrational frequencies are independent of temperature in a strictly harmonic solid: that is, one in which the interatomic forces are taken to be linear functions of the displacements. Thus, the theoretical framework must accommodate the non-linearity of such forces. Roger developed the necessary tools, treating anharmonic effects by perturbation theory. He was one of the true trail-blazers here. Comprehensive accounts of the anharmonic properties followed, including phonon lifetimes, the temperature dependence of frequencies, dielectric properties and thermal expansion (2). Much of this was accomplished while he was still a graduate student.

I might note that I came to Chalk River as a summer student in the neutron group in the summer of 1963, shortly after Roger had returned to Cambridge to finish his thesis. I cannot tell you how stimulating the environment was in this group. Brockhouse had gone off to McMaster University but, like Roger, I was able to work with Dave Woods and Gerald Dolling. Even though I had not yet begun graduate school, they both treated me and my fellow summer student, John Cordes, like established scientists. Specifically, they gave us a remarkable amount of independence in our summer project, measuring and analysing the phonon spectra in nickel metal. This experience had a profound effect on me in my career as an experimental physicist for the next five decades. I know that Roger profited just as much from the early Chalk River experience.

The production of Roger’s thesis was very much a family effort. His father typed it and his future wife, Sheila (née Wells), produced many of the graphs, bending lengths of rubber to get the right shape to fit the data. Roger had met Sheila at the Youth Club of the Congregational Church in Romford before going up to Cambridge. The Saturday evenings there were spent playing table tennis and dancing. Later on, their dates usually involved some activity such as boating or pitch and putt in the local parks, tennis, walking or dancing. They married at the end of his student days on 4 April 1964 and went to North Wales for a honeymoon. This included climbing Snowdon and walking along the serrated ridge of Crib Goch.

**Early career at Chalk River**

Shortly after finishing his doctorate, marrying Sheila and going on their honeymoon, Roger, together with Sheila, went by ship (the *Empress of Canada*) to Montreal to start work at Chalk River. Since Roger had learned to skate and ski as well as play bridge during his year in Deep
Biographical Memoirs

River as a student, he was happy to be able to resume these activities. For summer recreation the couple would go camping and canoeing in primitive campsites at weekends. They were both keen members of the Deep River Yacht and Tennis Club. About once a year they would canoe across the Ottawa River (about 2 km wide) to climb Mount Martin (only 300 m high) in Quebec, from where there is a spectacular view across the Ottawa Valley and Laurentian Hills. Roger and Sheila had two children, both born in Deep River, Sandra in December 1966 and Kevin in April 1969.

Roger had an extraordinarily productive research career at Chalk River, spanning the period from 1964 to 1970. His formal appointment was as a research officer with AECL. It happened that I was a summer student at Chalk River in 1964 when he first turned up with his charming young bride. I remember that the excitement among the scientific staff over Roger’s arrival was palpable. He had already produced brilliant work as a graduate student and the researchers knew that he would immediately start doing new and exciting research as an independent scientist. Although Bert Brockhouse had left Chalk River, he had left behind an exceptional research team, including notably Dave Woods and Gerald Dolling. Later Bill Buyers, Tom Holden and Eric Svensson joined the group. Roger worked exceptionally well with his coevals so together they ensured that Chalk River would continue as one of the world’s leading neutron-scattering centres.

As might be expected, Roger continued his work on lattice dynamics and structural phase transitions, including, in particular, his work on soft modes and structural phase transitions in incipient ferroelectrics such as SrTiO₃ (6). He and his collaborators carried out detailed measurements of the phonon dispersion relations in insulators, semiconductors and metals. This, in turn, enabled the determination of the interatomic forces, leading to the use of the shell model for ionic crystals and the pseudopotential method for metals. In order to describe the behaviour of the lattice vibrations accompanying structural phase transitions, it was necessary to go beyond the harmonic approximation since the vibrational frequencies are independent of temperature in a strictly harmonic solid. This meant that the theoretical framework needed to be expanded to include the non-linearity of the interatomic forces. Roger developed the necessary theoretical tools, borrowing techniques established in particle theory (2, 3). This foundational work continues to be important to this very day.

In parallel with his work on the lattice dynamics of solids, Roger joined with Dave Woods to carry out a comprehensive inelastic neutron-scattering study of the thermal excitations in normal and superfluid liquid helium-4 (7). These classic measurements provided incredibly detailed information on the phonon and roton dispersion relation in helium-4. They showed, in addition, the crossover from collective phonon excitations at low momentum transfers to the scattering expected from almost free helium atoms at large momentum transfers. From a detailed study of the energy widths in the normal and superconducting states, Roger and Dave obtained evidence for macroscopic occupation of the zero-momentum superfluid state, and compared their comprehensive experimental results with the theoretical predictions extant at that time. These classic experiments are still cited extensively nearly five decades later.

During this time, Roger also began a long and productive collaboration with W. J. L. (Bill) Buyers (figure 1), studying the magnetic excitations in a variety of materials, ranging from model magnetic insulators such as MnF₂ to, in later years, high temperature superconductors. This included studies of localized modes in doped antiferromagnetic insulators, measurements of excitations of mixed spin and orbital character in materials such as CoO and CoF₂ (4), two magnon scattering in simple anisotropic antiferromagnets, and studies of the magnon–phonon interaction in UO₂.
Edinburgh

After this extraordinarily productive period at Chalk River early in his career, Roger was recruited at the age of 30 to be a Professor of Physics at the University of Edinburgh. As Sheila recounts, here they spent 18 happy years exploring the hills and coastal areas of Scotland, renting a summer cottage in a different area for one or two weeks every year. Attempts were made to ski in Scotland but the weather was so unreliable that it made planning ahead difficult. Many summers were spent at Brookhaven National Laboratory (BNL) on Long Island, New York, where Roger was an enthusiastic member of the summer research programme and the family enjoyed the friendship of other visitors. They stayed on site and Roger would always buy a couple of second-hand bicycles and repair them as necessary, so that the children had the freedom to cycle around the site and housing area for the six weeks that they were there. It was a wonderful opportunity for the Cowley children to get to know people from many different countries and to play in a multi-cultural group. My own four children still talk about the wonderful times that they had with Kevin and Sandra during these summer sojourns at Brookhaven.

Life at the university

Immediately after arriving at Edinburgh, Roger became actively involved in the life of the department and the university. He was equally gifted as a researcher, classroom teacher,
graduate student supervisor, postdoctoral fellow advisor and administrator. Keith Refson, who was both an undergraduate and a PhD student in Physics at Edinburgh in the late 1970s and early 1980s, has a charming memory of Roger as a classroom teacher:

My first memory of Roger Cowley is still a powerful one. On the occasion when he welcomed our 1978 cohort to the physics undergraduate course, he gave a very inspiring speech, telling us that we had chosen a subject of enduring importance. Discoveries in physics would be remembered for many hundreds of years, long after works in other fields were forgotten. Roger invariably managed to bring a sense of fun and a distinct air of eccentricity to his lectures. These were peppered with an energetic and occasionally absurd use of metaphor to emphasize a point. Later, I came to understand more of the man and how this originated in his offbeat sense of humour, which he used rather effectively to enliven his teaching. At the time, his sayings were a notable talking point among the students.

Roger’s good nature, quiet determination and energetic commitment extended beyond the leadership of his research group. Specifically, he had a natural gift as an administrator, although his administrative ambitions never extended beyond being a department chair or head. He was elected head of department at Edinburgh twice, serving for a total of seven years. During his headship, he drove a root-and-branch restructuring of the department’s undergraduate teaching programme, did battle with colleagues and PhD students on the badminton court, and led final-year students on hill walks. His style of management was based on sincerity, trust and a wry sense of humour. Rather than telling people what to do, he would make little suggestions and then allow people to get on with things.

Of course, Roger truly excelled in research. Immediately after arriving at Edinburgh, he established a highly productive research programme with a mixture of theory and experiment. He and his students carried out measurements at neutron facilities around the world. Many of his group members went on to have distinguished careers of their own.

As he had already demonstrated as a graduate student at Cambridge and a researcher at Chalk River, Roger was exceptionally gifted at theory. At Edinburgh, he founded a highly productive research programme in the theories of structural phase transitions. Underlying this were his efforts to understand the soft mode behaviour in SrTiO₃ but his research soon extended far beyond that. Much of this theoretical work was carried out in collaboration with an exceptional young theory student, Alastair Bruce. One of Roger’s most influential theoretical contributions was an application of Landau theory, together with the renormalization group technique introduced by Ken Wilson and Michael Fisher. Alastair Bruce has noted that it took Roger only a day or two after the emergence of the renormalization group technique to see how to adapt it to give an account of critical phenomena at the SrTiO₃ transition. He was thereby able to break down various possible structural phase transitions into different universality classes and to determine whether or not they would exhibit classical or critical phase transition behaviour. This was a conceptual breakthrough for experimentalists like myself who found the initial Fisher–Wilson theory extraordinarily challenging. Because of Roger, we were able to understand the key physical ideas of marginal dimensionalities straightforwardly and were thereby able to incorporate them into our research and graduate teaching.

Along with Alastair, Roger carried out extensive studies of the theory of incommensurate systems and commensurate–incommensurate phase transitions. Again, this theoretical work
motivated a plethora of experiments on incommensurate systems in one, two and three dimensions. He and Alastair also wrote a highly influential book together on structural phase transitions (10).

Meanwhile, Roger continued to carry out experimental studies on many different fronts. His first experimental student at Edinburgh was Bill Stirling (figure 2). Bill describes Roger as a thesis supervisor and a human being as follows:

As we all know, Roger was a determined man but somewhat shy. It was not that he avoided direct face-to-face contact; rather he employed what would be called today ‘soft power’. Small pieces of paper would appear on my desk with scribbled comments, always in pencil, ‘It might be nice if you were to try . . .’ and I was directed towards several months of work. Roger was rigorous in his research, teaching and administration but kind and thoughtful with his colleagues. He showed us, his students and postdocs, what scientific research was all about. He would look at the data from an experiment or the results of a long computer calculation, and after some consideration he would murmur, ‘It’s about right’ or ‘There’s something odd here’.
Bill worked on a variety of research problems for his thesis, including further studies of Roger’s beloved SrTiO₃. Singular among their collaborative works was their pioneering neutron-scattering measurements of the excitations in helium-3 (8). These experiments showed the zero sound peak and how it decayed into the continuum. Measurements were also made for helium-3/helium-4 mixtures.

After one of his trips to the US, Roger decided that he wanted to create at Edinburgh a high-resolution triple axis X-ray spectrometer facility using a rotating anode as the X-ray source. This would give him and his colleagues at the university an in-house capability for studying many of the systems that had previously been probed primarily with neutrons. This new venture was started up under a research council grant jointly held by Roger and his colleague Richard Nelmes. Tom Ryan, who was at that time a technician in Nelmes’s laboratory, was tasked with actually making it happen. Tom comments:

By 1980 the machine was operational. Suddenly, the papers started to flow. It seemed that every material we studied showed some interesting new behaviour. Our very first paper was published in Physics Review Letters. We studied phase transitions. We measured critical exponents. We looked at incommensurate crystals. When I started a PhD with Richard and Roger, despite not having the usual physics degree background, Roger, in his typical style, convinced me that it would be easy. Through the early 1980s, we continued to produce a large body of work that was aligned with Roger’s theoretical work on phase transitions. The lab was a merry-go-round of visitors from all over the world.

One of the most important pieces of research to emerge from this facility was Roger and Steve Andrews’ discovery and characterization of ‘surface truncation rods’ (12). Steve Andrews was a postdoc with Roger in Edinburgh between 1981 and 1984. In the course of studies of conventional structural phase transitions, Roger and Steve noticed that all of the crystals in these studies exhibited diffuse scattering streaks around the Bragg peaks that were perpendicular to the surface in reciprocal space. They soon realized that these streaks were simply caused by truncation of the periodic lattice at the surface and that the shape of these ‘crystal truncation rods’ (as they have become known) contained detailed quantitative information about the surface structure and topology. Interestingly, their first attempts at analysing scattering data from rough crystal surfaces were made using a simple theory by Michael Berry that had been developed to describe the scattering of radar from polar ice fields. The applicability of the theory is not as surprising as it might first appear because the ratio of wavelength to characteristic feature size is similar in the two problems. These initial studies, which were somewhat crude by modern standards, have underpinned a great deal of later synchrotron work on surface and interface atomic structure and surface phase transitions in systems as exotic as correlated electron materials.

In these early X-ray experiments, Roger, Tom Ryan, Richard Nelmes and Alain Gibaud also discovered an anomalous effect in the material RbCaF₃ known as the ‘two-length-scale problem’: that is, apparent critical fluctuations with a length scale much larger than that associated with the normal thermal critical fluctuations. This became a heated and rather controversial subject of research. It happened that my own group carried out some measurements on a quite different material, CuGeO₃, which nevertheless showed the same large length-scale fluctuations and we produced a theory based on Roger’s and my earlier research on the random field problem. I remember well Roger expressing his admiration for
the experiments but saying that the theory, even though it was based on his own work, was not correct. In that case we simply agreed to disagree.

Roger was also strongly linked to the Edinburgh light-scattering group headed by William Taylor and including David Lockwood as a research fellow (figure 3). One particularly notable result to come out of this collaboration was the measurements by David and his collaborators, using light-scattering techniques, of the amplitude and phase modes predicted by Bruce and Roger in incommensurate solids. Alan Murray, a PhD student in William Taylor’s group from 1975 to 1978, recalls: ‘Roger’s involvement with the light-scattering programme was occasional and the only direct work that I did with him was on some of the theoretical soliton stuff; this also involved Alastair Bruce. But Roger had great influence on all our work as a catalyst.’

**SABBATICAL AND Summers AT BROOKHAVEN**

As noted above, the Cowleys were frequent visitors to Brookhaven. During these visits, Roger collaborated with many different people at BNL and worked on a variety of subjects that interested him. He also worked with many of the post-doctoral fellows during his visits and they benefited immensely from his mentorship. Steve Shapiro, one of the senior physicists who collaborated extensively with Roger comments:

Perhaps Roger’s most significant work was the collaboration with Gen Shirane and Bob Birgeneau on disordered antiferromagnets, in particular, the random field Ising model materials. This was a ‘hot’ topic of the period and their work was definitive in delineating and solving the problem. In Roger’s last visits he worked with me and others and studied the 2-length problem in SrTiO₃, something Roger discovered using x-rays in Edinburgh. Roger spent a year with his family in the middle 1970s living not too far from my home. He and Sheila invited us for dinner one evening.
and we had difficulty finding his house. We saw a neighbor and asked if he knew where an English family lived. He responded, ‘Oh, they are the ones that take walks.’

After that year, Roger and his family spent several summers at BNL. A cold source was installed at the HFBR [high flux beam reactor], but it was not very effective and since the intensity was quite low there was not much demand. This suited Roger very well, in that he could work in peace and set up very long scans. This allowed him to go to the beach with his family and spend some more time on the tennis courts. Roger’s modus operandi seemed to be to collect some high-quality data during his summers at BNL and then return back to Edinburgh or Oxford and do the analyses and write the papers, which he always did. There were many fun times at the beaches and Bar-B-Q’s at homes. Roger also was a mainstay on the BNL tennis courts and we had many wonderful matches. He was a very good tennis player and when we played doubles, Gen usually would tell Roger that he was his partner so that Gen would have a competitive edge playing with the better player.

As Steve notes, Roger, Gen Shirane and I worked extensively together on the phases and phase transitions in model magnetic systems. This was one of the most enjoyable and intellectually stimulating periods in my research career (figure 4). Our focus was on the effects of dimensionality and disorder, often combined. The collaboration began in the middle 1970s, while Roger was on sabbatical at Brookhaven, and lasted for the next 15 or so years. He and Sheila would come to Brookhaven for extended periods every second summer. Roger and I, with Gen looking over our shoulders, would run experiments continually while our kids organized all kinds of activities on the Brookhaven lab site. It was a wonderful combination of great science and stimulating family life. These were among the few times that Roger and I could actually run the experiments ourselves rather than having the work done by graduate students and postdocs. Roger, in particular, seemed to get great pleasure out of the data analysis. He would appear at all hours with stacks of computer printout showing me the results of his latest fits.

We mostly studied two- and three-dimensional transition metal fluorides such as MnF$_2$ as model systems. Diluting the magnetic ion with a non-magnetic ion (for example, in Rb$_2$Mn$_{1-x}$Mg$_x$F$_2$) allowed us to study the effects of disorder on both the excitations and the phase transition behaviour. Tuning $x$ to the percolation threshold allowed us to study the effects of percolation in a well-controlled manner (9). This, in turn, introduced the concept of ‘fractals’ in a solid-state system. By varying the transition metal ion, we were able to study Heisenberg, XY and Ising model systems.

One of the most exciting developments occurred when Amnon Aharony and Shmuel Fishman pointed out that applying a uniform magnetic field to a disordered antiferromagnet would generate a random staggered field. For the first time, this opened up the possibility of studying in a systematic way the exotic physics of random field disorder, particularly in Ising systems. We launched a series of experiments on both two- and three-dimensional random field Ising magnets. We discovered empirically that the results were strongly affected by the breakdown of equilibrium, meaning that equilibrium statistical mechanics could not predict the observed behaviour (11). Not surprisingly, this generated a great deal of controversy but also exciting new physics. Throughout this challenging research, Roger always behaved calmly and logically, not rising to the bait of the provocateurs, to the great benefit of the physics. These ‘model magnetic system’ experiments carried out by Roger primarily at Brookhaven set the standard for the field and continue to do so today.
In 1988, Roger went to Oxford as Dr Lee’s Professor of Experimental Philosophy and a Fellow of Wadham College. At Oxford, he missed the sea and the hills, but with a tennis court at home and a larger garden he spent more time involved with these at-home activities. He also enjoyed the grass tennis courts in the University Parks. The family took advantage of the opportunity for croquet in the Fellows’ Garden at Wadham; if they timed it well the mulberry tree would be in fruit, which was a bonus. Roger never lost or hid his competitive spirit and he enjoyed spreading the opponent’s croquet balls to the far corners of the garden. Punting was another skill he had learned in Cambridge and could use in Oxford, although he rather objected to having to punt from the other end.

Sandra married in 1988 and Kevin in 1999 and the family grew with the addition of six grandchildren, in whom Roger took much delight and interest and with whom he loved to spend time. In 1992, the Cowleys started the tradition of renting a cottage for a week at
Eastertime and inviting all the family to join them. Roger was the leader of the walks and could always be relied on to buy a round of ice creams at the end.

Roger enjoyed all sports; he had his own effective style in tennis and skiing but never the rhythm or technique of a professional. He also delighted in playing board and card games with the children and then grandchildren. He returned to playing bridge regularly after his retirement. He took a keen interest in politics and society and he said this was due to the influence of his maths teacher at Brentwood, who had introduced him to such books as George Orwell’s *Nineteen eighty-four* and Alan Paton’s *Cry, the beloved country*. He read *The Times* newspaper from cover to cover every day, but was not a reader of novels, preferring to be active as an alternative to his work. Somebody once said: ‘Roger’s idea of a rest is to do something different.’

Fiercely independent, Roger avoided having any workmen to do jobs that he was able to do himself, because he found that satisfying. Gardening was a good opportunity to clear his mind and think about the political problems that came with his job, and he spent a lot of time and effort in the garden. He was also very handy about the house and was keen to do the maintenance himself wherever possible. He would tackle any wood-working or electrical task, but never plumbing, saying that he understood electricity but that the opportunity for a mess was too great with plumbing.

**TEACHING AT OXFORD**

James Analytis, who is now a professor at UC Berkeley, recalls the following about his experiences with Roger as a teacher at Oxford:

In my first year as a graduate student at Oxford, Roger Cowley taught a course on the band theory of solids, from the tight-binding method to the basics of density functional theory. He was an extraordinarily broad physicist, though clearly driven by experiment. Roger didn’t suffer fools gladly and wanted to get quickly to the scientific question at hand. I remember coming to him during his office hours for help on a problem set. I started apologizing for the state of my handwriting and the ostensibly random scrawls of text all over the question sheet. Before finishing my excuses, he said, without flinching, ‘It shows you’ve worked on it. Now let’s get to your question.’ This directness left an impression on me, and I still value the importance of quickly distinguishing what matters from what really doesn’t.

‘I joined a research group that was closely connected to his, and we would often sit at the same table together during tea, along with Bill Hayes, Stephen Blundell, Arzhang Ardavan, Radu and Amalia Coldea and John Singleton. Bill would often have a witty anecdote from his youth to share, John would sometimes bring a passage of poetry to read to us, and Steve would reveal his most recent discovery of the character peculiarities of great physicists. I remember Roger enjoying these conversations, but he would always pull the conversation back to the matter at hand: physics. In this bi-polar company, this would have been a struggle for anyone else, but Roger had a sense of authority about him, not because of his esteemed position (he was department Chair at the time), but because it was understood that he only spoke when he had something meaningful to say, and not before. With varying degrees of failure, I have aspired to his example, and continue to do so.

**LIFE AT WADHAM COLLEGE**

Roger was an active member of Wadham College, enjoying his college life as a Fellow. He did not have teaching duties in the College but Jeffrey Hackney, Wadham Emeritus Fellow
Roger Arthur Cowley, and Keeper of the Archives, notes that Roger’s advice in committees on scientific matters was freely given and always attentively listened to. The combination of his science background and his very considerable managerial skills was an invaluable part of the Fellows’ discussions of academic matters across a wide range of subjects. Roger was generally viewed as a congenial and open-hearted colleague, blessed with an enormous amount of common sense. He was especially welcoming of new colleagues and he took an active role in supporting the social side of Wadham life. Amusingly, he was in charge of the ‘optional’ dessert after dinner, an interesting assignment for such a brilliant physicist. Lord Macdonald, the current Warden of Wadham College, says: ‘It would be quite impossible to find anyone at Wadham who did not harbour the highest regard for Roger. He was a marvellous man and he is missed very much.’

NEW RESEARCH DIRECTIONS

Roger’s move to Oxford gave a fresh impetus to his research. For example, his interests in magnetism were extended to quantum magnetism: that is, magnetic systems that possess a high degree of quantum entanglement and whose properties are governed by quantum fluctuations. A seminal work was the observation with Steve Nagler of fractional spin excitations, called spinons, on spin-half antiferromagnetic chains (15) (figure 5). This work began in 1990, when Steve came on sabbatical to Oxford from the University of Florida. He had first met Roger at Chalk River where he (Steve) was working as a graduate student and, like many of us, was a great admirer of Roger. They decided that as one of their research projects they would explore the spin dynamics of a quasi-one-dimensional $S = 1/2$ system $\text{KCuF}_3$. This led to a comprehensive study of the spin dynamics in $\text{KCuF}_3$ as a function of energy and temperature. This work built on earlier studies in the 1970s at Brookhaven/Bell Labs on one-dimension quantum $S = 1/2$ chains, which were interpreted on the basis of semiclassical spin wave theory. However, advances in the theory in the 1980s suggested a richer picture in which there is a continuum of excitations composed of unbound spinon pairs. Here, spinons are $S = 1/2$ quantum solitons. The measurements of Roger, Steve and a graduate student, Alan Tennant, confirmed in detail the predictions of the field theory model for the $S = 1/2$ chain, thereby validating this approach to the theory. This work complemented similar experiments in an $S = 1$ chain system where, as predicted by Haldane, rather different behaviour obtains.

A second new and quite different direction for Roger’s research was the study of metallic films. This was prompted by the installation of equipment in the Clarendon Laboratory for the layer-by-layer growth of metal films by molecular beam epitaxy. Roger exploited the X-ray and neutron diffraction techniques he had developed earlier to elucidate the structure and magnetic behaviour of these artificial crystals, especially ones made from alternating layers of different rare earth elements, such as holmium or erbium alternating with non-magnetic yttrium. These detailed investigations showed that magnetism can propagate from one magnetic layer to another even when the intervening layer is non-magnetic. The work uncovered a large number of exotic and novel magnetic phases, and contributed new insights into the theory of magnetism in metals.

In parallel with this work on metallic films, Roger studied the magnetism in elemental rare earth metals. This was, in part, stimulated by his long-standing interest in structural
phase transitions and, in particular, the theoretical work that he had undertaken with Alastair Bruce on incommensurate systems. The inspiration for this link was the high-resolution X-ray magnetic scattering experiments of Doon Gibbs and collaborators at Brookhaven. The Brookhaven experiments revealed that, instead of the pitch of the magnetic helix in elemental holmium evolving smoothly with temperature, it did so through a series of commensurate–incommensurate phase transitions, with the commensurate ‘spin-slip’ structures forming a soliton lattice. While the data of Gibbs and his co-workers established the special commensurate wave vectors at which the spin-slip structures formed, they could not provide a detailed microscopic model. This could only be achieved by studying the higher-order diffraction harmonics of the soliton lattice, which Roger achieved through a series of detailed neutron diffraction experiments (13). These experiments and their interpretation provided an important step forward in our understanding of one of the most fascinating magnetic elements,
and laid the foundation for a significant body of work on the rare earths spanning the period from the late 1980s to the early part of the present century.

Roger realized that the very detailed neutron diffraction data he had obtained on holmium provided the opportunity to test the then current models of rare earth magnetism. This ultimately led to an important revision of our understanding of interactions in rare earth metals. In support of this work, he initiated what proved to be a productive collaboration on the theory of rare earth magnetism with Jens Jensen and Allan Macintosh in Copenhagen (14). At that time, Jensen and Mackintosh were putting their finishing touches to their seminal book *Rare earth magnetism: structure and excitations*. The collaboration was extended naturally to include the experimental group at Riso National Laboratory, where most of the experiments were subsequently performed (16, 17).
Roger continued to carry out research on other systems of interest to him, many connected to his long-time interests in structural phase transitions and low-dimensional magnetism. Prominent among the former were studies of highly disordered incipient ferroelectrics known as ‘relaxors’ (19). The latter included studies of the bicritical behaviour in two- and three-dimensional uniaxial antiferromagnets, with and without disorder, as well as measurements of the spin fluctuations in high temperature superconductors (20). The experiments with superconductors were carried out in collaboration with Bill Buyers at Chalk River. Indeed, in some ways Roger came almost full circle in his research after nearly five decades.

Roger and Sheila were inveterate travellers. Figure 6 shows them at Milford Sound, New Zealand in 2004, when Roger was on an exchange programme for one semester at the University of Christchurch. The last time that my wife, Mary Catherine, and I were together with Roger and Sheila was in May 2013 during a vacation trip that they were taking on the US west coast. I was in the process of completing my service as the Chancellor of UC Berkeley, about to resume the life of a regular faculty member. We were in the midst of moving from the 2000 m² house that the University provides to its Chancellor to a much more modest house in the neighbouring community of Orinda, in which Roger and Sheila were our very first guests. We could not have imagined that this would be the last time that we would be together as couples, 49 years after our first meeting in Chalk River.

Roger formally retired from Oxford and Wadham College in 2007 (figure 7), then becoming an emeritus professor of physics at Oxford and an emeritus Fellow of Wadham College. Overall, he supervised 25 PhD students and 21 postdoctoral fellows. Many of these physicists went on to distinguished research and academic careers of their own. Roger continued to be active in research right up until the time of his bicycle accident (21). The primary focus of his
post-retirement research was on two very different subjects: relaxor ferroelectrics and neutron scattering from hydrogen at high energies (18). He continued to carry out ground-breaking, original research right up to the end of his career. All of us aspire to do the same.

ADMINISTRATION

In spite of the fact that Roger’s focus was always on teaching and research, he was a naturally gifted administrator. He served as Head of the Physics Department in Edinburgh for seven years and Chairman of the Physics Department in Oxford for eight years. He was a member of British Research Council committees including Physics, Neutron Beam Research and Synchrotron Radiation, as well as the Science Advisory Committees for the Institut Laue-Langevin, the European Synchrotron Radiation Facility, Spallations-Neutrenquelle and ISIS. He was a member of the Physics Panel of the EEC Committee for the European Development of Science and Technology and a member and Chairman of the International Union of Pure and Applied Physics Commission C9.

Roger was an editor of many learned journals, including being the founding Editor-in-Chief of the *Journal of Physics: Condensed Matter*. He was a member of international committees to review physics in Norway and Switzerland, the ETH, Uppsala University and the NRC Laboratories in Ottawa. For the University of Oxford, he was a member of the General Board of the University and Chairman of the IT Committee, as well as chairman of several departmental reviews. Finally, he was a member of the Council of the Royal Society.

HONOURS AND AWARDS

1972 Fellow of the Royal Society of Edinburgh
1973 Max Born Medal and Prize from the Institute of Physics and the German Physical Society (first recipient)
1978 Fellow of the Royal Society
1990 Holweck Medal and Prize from the Institute of Physics and the French Physical Society
2001 Fellow of the Royal Society of Canada
2003 Walter Hälg Prize from the European Neutron Scattering Association
2008 Faraday Medal and Prize from the Institute of Physics

ACKNOWLEDGEMENTS

I am extremely grateful for the generous and extensive input that I have received from many people including, first and foremost, Sheila Cowley. The list of contributors to this biographical memoir includes James Analytis, Andrew Boothroyd, Alastair Bruce, Bill Buyers, Paul Clegg, Jeffrey Hackney, Lord Kenneth Macdonald, Desmond McMorrow, Alan Murray, Stephen Nagler, Richard Nelves, Keith Refson, Tom Ryan, Steve Shapiro and Bill Stirling. They all share a common love and respect for one of the great physicists of our time.

Frontispiece photograph courtesy of Wadham College, University of Oxford.
Robert J. Birgeneau is the Arnold and Barbara Silverman Distinguished Professor of Physics, Materials Science and Engineering, and Public Policy at University of California, Berkeley. He received his PhD in Physics from Yale University. Following time working at Yale, the University of Oxford and Bell Laboratories, he arrived at MIT in September 1975 as Professor of Physics. In 1988 he became head of the department and in 1991 Dean of Science at MIT. In 2000, he became President of the University of Toronto. In 2004 he was appointed as Chancellor of UC Berkeley and joined the Physics faculty. An internationally distinguished physicist, he is a leader in higher education and is well known for his commitment to diversity and equity in the academic community. Under his leadership UC Berkeley became the first university in the United States to offer comprehensive financial aid to undocumented students. He is a fellow of the US National Academy of Sciences, the Royal Society, the American Philosophical Society and other scholarly societies. He has received many awards for teaching and for his research on the fundamental properties of materials.

Bibliography

The following publications are those referred to directly in the text.


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