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John Barratt Moore 1941–2013

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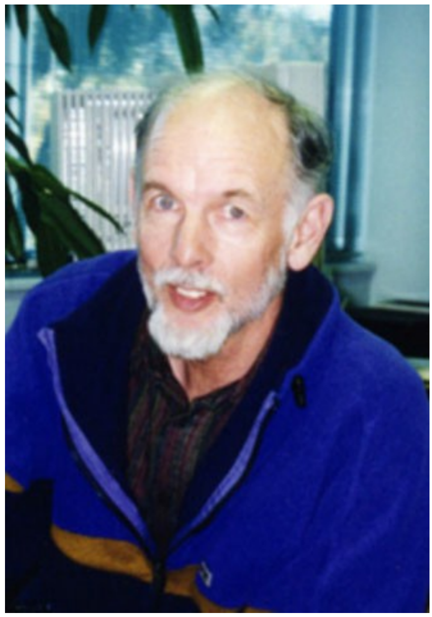
John Moore was born in Lungling, China on 3 April 1941 and died in Canberra on 19 January 2013. He was an electrical engineer who spent most of his distinguished career at the University of Newcastle and the Australian National University following industrial experience and graduate education in Silicon Valley, California. He was a Fellow of the Institute of Electrical and Electronic Engineers, the Australian Academy of Science and the Australian Academy of Technological Sciences and Engineering, achieving all honours at a comparatively early age, and was recognized principally for his contributions to the field of control systems.

Family Background

John Barratt Moore was born in Lungling, China on 3 April 1941, to Gilbert Llewellyn Moore and Kathleen Letitia Moore (nee Davies). Both his parents were missionaries of the Methodist Church and his mother a trained nurse. They had met in Australia, and again on a ship travelling to China, and though sent to different parts of China initially, in due course married. His forbears had also worked in the service of the church and John's middle name, Barratt, celebrates one such person, David Barratt, who was tortured and executed during the Boxer uprising in China. John was the second of two sons, and his elder brother Paul became a minister in the Methodist, and later Uniting, Church and a counselling psychologist in private practice.

The Japanese were engaging in war operations in China well before the Pearl Harbor attack, and in the face of their advance in China, the family returned to Australia in late 1941. They lived in several locations in Victoria, where John's father was ordained as a minister at the Methodist Church, holding appointments in Pimpinio, Minyip, Goroke and later Seymour. He died prematurely from cancer when John was 11 and the family then moved to Brisbane to reside with John's maternal grandmother, who helped raise the two boys. At the age of 25 and while living in California, John married Janice ('Jan') Nelson, who had grown up in Iowa but moved to California to practice as a dental hygienist. Very shortly thereafter, they moved to Australia, to Newcastle, New South Wales,



where two sons, Kevin and Alan, were born. Subsequently in 1982 they moved to Canberra, where Kevin obtained a PhD in computer science and Alan a double bachelor degree in Engineering and Computer Science. Both married, and at the time of John's death there was one grandchild, resident in Canberra. His wife Jan continues to live there.

School Education

Following the move to Queensland, John was educated at Ashgrove Primary School and

Brisbane State High School. In Brisbane, he was placed in a class with pupils of much higher average age than him and he struggled initially, but he was successful at the Queensland senior certificate examination to the extent of winning a Commonwealth Scholarship, which paid the cost of university fees. At the age of 16 he entered the University of Queensland to study electrical engineering.

University of Queensland

John completed his four-year undergraduate degree at the University of Queensland in 1961 aged 20, but, perhaps surprisingly in the light of his later career trajectory, only received second-class honours, although he appears to have been ranked second in his graduating year. His thesis was entitled 'Transistor Amplifier for a Pen Recorder unit'. Electronic Engineering was in transition from building systems using vacuum tubes to building systems using transistors, and no doubt this thesis project was like many at the time in reflecting that transition. Nevertheless, out of it and extremely unusually for the time came a publication in the *Journal of Scientific Instruments* entitled 'A water wave recording instrument for use in hydraulic models' [1]. Following the undergraduate degree, John enrolled at the same university for a full-time Master of Engineering Science degree, graduating in 1962. His thesis continued the electronics theme, being entitled 'Generalized Transistor Class C Amplifier Analysis and Design'. This appears not to have given rise to any journal or conference publication.

Silicon Valley

Upon obtaining his Master's degree, John applied for jobs inside and out of Australia, and was offered a job in Vancouver, Canada. On arriving there, he found that the job location had shifted to Nova Scotia and he decided to forego the job and instead to try his luck in the USA. After a 99 day for 99 dollars Greyhound bus tour of the US, he ended up in Silicon Valley, perhaps not surprisingly, given his interest in electronics. He was offered a position by Fairchild Semiconductor, who sponsored him for the necessary green card. Fairchild Semiconductor was one of the leading companies working on the next transition in electronics technology, from transistors to integrated circuits. While there, he designed a device named the MicroLogic 926, which was the world's first integrated circuit JK flip-flop (a form of digital switch). However, in a move that proved decisive, while remaining at Fairchild he enrolled in some part-time courses offered outside work hours in the department of electrical engineering at the University of Santa Clara. This was a private university that generated immense income from part-time master courses, especially in engineering, serving the local Silicon Valley industry. The university had decided to expand its horizons and had initiated a doctoral programme, which was fortuitous for John. He was offered a scholarship to do a PhD and he accepted the offer, leaving Fairchild.

University of Santa Clara

John's principal doctoral supervisor was D. D. Siljak but he also enjoyed close technical contact with Richard Dorf, then the department head of electrical engineering and later Dean. John and Siljak both subsequently became Fellows of the Institute of Electrical and Electronic Engineers (IEEE), John before Siljak; Siljak would draw attention with pride to this achievement of John's, saying it marked the distinction between the two of them. Siljak himself at the time was a young immigrant to the USA from Yugoslavia, about ten years John's senior, and he had studied for his PhD with a famous control systems engineer. Accordingly, he introduced John to the field of control systems, which remained central to John's research for his whole career. Classical control engineering, especially design methods, was heavily dependent on a range of graphical techniques, special charts, rules of thumb for drawing the relevant graphs and so on, and John's thesis work was an attempt to generalize some of these ideas while retaining their graphical flavour. The generalization was to generate feedback controller designs where two physical parameters associated with the system being controlled could undergo substantial variation, with the designed controller supposed to ensure that the effects of those two variations had minor effect on the overall system performance. The name 'parameter plane design' was applied to this approach. While successful in the narrow sense of developing new knowledge, the rapid advance of computers and more generally of what was known as 'modern control' soon rendered this work old-fashioned, and it may have been one of the last PhD theses anywhere treating a 'classical' control problem with classical control methods. It was as if one had done a development in vacuum tube technology when most of the world had moved on to use transistors or integrated circuits. Nevertheless, John published a modest collection of papers on the idea, both during and after his PhD, [2], [5], [40].

A technical aspect of the parameter plane design approach, in common with much control design, was the need to be able to find zeros of polynomials. While for a quadratic $ax^2 + bx + c$, most secondary school students can find its zeros using a well known formula, there is no formula available when the polynomial degree exceeds four and computer programs are necessary. In 1965, computers were very primitive by today's standards, and there was great art behind programs to ensure that they would complete a polynomial zero-finding calculation in reasonable time. This led John to write a polynomial zero-finding algorithm published in [3] that later was adopted by IBM as a standard on their machines for many years. Presentation of the material also won him a student paper prize at an IEEE meeting in the San Francisco Bay Area.

During his student days in California, John met Brian Anderson, who was a student and then faculty member at Stanford University. Brian accepted an offer of a foundation chair in electrical engineering at the University of Newcastle in late 1966, at which time John was very close to completing his PhD. With several posts to be filled at Newcastle, the two spoke about John's moving to Newcastle. At that time, John was very embedded in the US culture, about to marry an American in a steady job, and starting to receive flattering and high-salaried offers of faculty positions in the USA, and at established locations. A long conversation at a conference in Allerton, Illinois proved decisive in tipping the balance to Newcastle and, in due course, John accepted an offer to commence as a senior lecturer. No doubt this would have been with a sense of adventure, if not risk, though with the knowledge that the green card and the favourable job market in the US provided a satisfactory escape route.

A Decade and a Half at the University of Newcastle

The electrical engineering department at the University of Newcastle at the time of John's arrival in 1967 (almost simultaneously with Brian Anderson) had no prior experience with offering a full undergraduate degree; it had simply served as a sub-department offering early-year service courses to civil, mechanical and chemical engineering students. There were four members of staff, none PhD qualified, but importantly, there were other vacant positions. These allowed a shaping of the department to create a research specialty, aligned with the overlapping interests of John and Brian Anderson, in what might be loosely today termed systems and control, that is, centred around control systems but spilling over into signal processing, circuit theory and, later, communications. The strategy persisted virtually to this day, and certainly was maintained when John at a later stage assumed the headship of the department. The strategy led to an inward flow of first-class students and academic staff members, many of whom went on to earn great distinction at later stages in their careers. Their names include Robert Bitmead, FTSE, Tony Cantoni, FTSE, Rob Evans, FAA, FTSE, Graham Goodwin, FAA, FRS, FTSE, David Hill, FAA, FTSE and Hung Nguyen, AM, FTSE.

John's promotions were rapid. Having been initially appointed as a senior lecturer, not an unknown phenomenon for a new PhD in those days who had some prior industrial experience, after two years he was an associate professor, and after another four and a half, was advanced to professor. At age 37 and at a much younger age than is typical, he became an IEEE Fellow. Perhaps he was the third in Australia at that time, and it was an unusual honour. Several of his former research students later achieved the same honour.

In the first years, John and Brian Anderson were each other's closest collaborators, and their work focused on control systems. There came several important joint papers on a technique of controller design that the evolution in computer technology had freed from the constraints of graph paper and hand calculation. One of the most important of these was a technique showing how, with the right problem formulation, one could ensure that the closed-loop system resulting from the design procedure would display any desired degree of stability [43]; this allowed a goal to be achieved that had often been part of design specifications when classical control methods were used, and perhaps gave greater confidence to designers used to classical methods to try the new approaches. Up to this time, 'modern' control approaches did not actually allow incorporation directly of such a goal. All this thinking led to work over 1969–70 resulting in a jointly authored book *Linear Optimal Control* [55]. This helped cement the foundations of John's growing international reputation. Some twenty years later, and in the light of the success of the first book, a type of second edition was written but with substantial changes and modifications, *Optimal Control: Linear Quadratic Methods* [144]. Dover Press reissued the latter book after another fifteen years or so [324].

A technical first cousin of linear optimal control was a signal processing technology known as Kalman filtering. Kalman filtering deals with the task of estimating what is going on inside a system using limited noisy measurements on that system. John devoted much energy to various problems in Kalman filtering, including one that had important applications ramifications. A variant of Kalman filtering is termed fixed-lag smoothing; the idea is to use noisy measurements on a system to determine what had happened previously, rather than what is happening at the time the most recent measurement has become available. So if one is interested in the internal behaviour of the system at time $t=10$, say, with normal Kalman filtering one uses measurements up to $t=10$, while with fixed lag smoothing, one uses measurements up to, say, $t=12$. Smoothing always uses more information than filtering and this should give a better quality estimate, but the penalty is the delay in producing a smoothed estimate: what was happening at time $t=10$ is only learnt at time $t=12$. The concept of fixed-lag smoothing went as far back as a classified wartime publication of Norbert Wiener, and various workers had attempted to translate the concept into the framework tackled by Kalman filtering. They were unsuccessful, though often without realising it. In fact, all the proposed implementations of a fixed-lag smoother had an inherent instability, which meant that with the slightest computational error or introduction of noise, the hardware device or computer program producing the fixed-lag estimates would diverge exponentially fast from what it was supposed to do. This was a fatal flaw. John and a student, Peter Tam, showed very cleverly how one could build a fixed-lag smoother using internal switching to eliminate the instability [75]. This work is not especially highly cited, but it is surely one of the most important contributions in this area.

John's work and choice of research directions were continually re-shaped through the extensive international network that he established. In the late 1960s and early 1970s, it was completely atypical for academics in Australian universities to travel abroad even once a year to a conference or research institution. One-year sabbaticals after six years were more the norm, with perhaps one overseas conference in between. Within less than a year at Newcastle, John had started to overturn this convention, utterly convinced from his time in the USA of the need for people who were to be internationally reputed to have on-going international exposure. In addition to conference trips, he had leaves at the University of Santa Clara (working with the Santa Clara water supply corporation), the University of Maryland, Imperial College (Fig. 1), the University of California, the Institut National de Recherche en Informatique et en Automatique (INRIA) in France and the University of Washington in Seattle, where he established what became a multi-year collaboration with Boeing.

Unsurprisingly, then, the subject matter of John's research was quite varied, with one major evolutionary trend: having started in control systems, it went on to embrace signal processing and thence to identification and estimation, prefiguring later work at the Australian National University. Within the control systems area, there was for example work on linear-quadratic optimization problems, Lyapunov stability, circle and Popov criteria and positive real transfer functions; see for example [8], [24], [25], [10], [38], [6], [15], [7], [16], [11], [27]. In the area of signal processing, there was work on Kalman filtering and its derivatives, detection of frequency modulated (FM) signals, spectral factorization, and pulse frequency modulation; see for example [42], [45], [46], [54], [57], [64], [66], [67],

Figure 1. John Moore teaching a graduate-level course at Imperial College, London in 1974, while a visiting professor there.

[69]. [71], [72], [76]. Early work on parameter estimation also included self-tuning filters, [80], [81], [87], [88], [90], [95]. No single one of these contributions stands out but in aggregate, they amount to a great deal. A fair proportion of the control work was summarized in his textbooks, highly cited to this day. And indeed, the work on Kalman filtering led to the publication of John's most highly cited work, *Optimal Filtering* [96], written jointly with Brian Anderson and frequently referenced by workers well outside engineering areas, such as econometricians.

One of the control contributions deserves to be singled out. Researchers, driven by many applications including existing applications, were trying to understand how to analyse and design decentralized control systems. One can envisage a physical system that is perhaps geographically distributed, like a power network, with localized generators and power sinks (that is, consumers of power). It is well understood that control systems must be placed at each generator to ensure that enough power is produced at the right voltage and frequency. It is intuitively reasonable that the controller for generator j would use measurements taken in the vicinity of generator j, but probably no measurements taken from any other (usually remote) generator k. Such an arrangement, where local measurements are used to generate a local control for a subsystem that is somehow connected to other subsystems, is known as a decentralized control system. There is an IEEE journal focused on such systems today, but thirty years ago, work in this area was unusual. John, together with Brian Anderson, established a very unusual (at least, unusual for the time) result [106]. To control such systems satisfactorily, it may be necessary to use a periodically-switching control law at each local subsystem; this is not one just where the value of the feedback control varies, but one where the parameters used to compute it are periodically switched. The intuition is that with one parameter setting, certain internal variables can be well controlled, but others cannot be; therefore, one has to switch attention from time to time and address the variables that have not been well controlled in the previous time interval. One might conclude that this reasoning could have been suggested by reflecting on the way democracies function; they always secure leadership change from time to time.

John's Other Contributions at Newcastle

John's greatest contribution outside his own research was to adopt international norms of research standards, research education and international interaction to put the Electrical Engineering department at the University of Newcastle on the international academic map. While outstanding personal research was part of the key, other necessary drivers of success were the attention shown to the recruiting process and the shattering of the university norms and expectations on upper limits for international interaction, including travelling abroad and bringing visitors. Any successful leader needs to be trusted and John had that trust. At the same time, he thought outside the square, in both a research sense and an administrative sense. Thus under his headship, the department's undergraduate programme expanded to include a degree in Computer Engineering, successfully accredited despite initial opposition from the accrediting authority, the Institution of Engineers Australia, since there was no precedent in Australia. With his research students, he embodied a supervision style of hands-on involvement with the student, rather than following the then still common British style that sometimes has been described pejoratively as supervision by osmosis.

The Australian National University

In mid-1981, the Australian National University (ANU) formed the view that it should introduce engineering in some way. The decision was taken to provide modest funds to start a department of systems engineering in the Research School of Physical Sciences, at that time part of the Institute of Advanced Studies. This led to the hiring of John Moore and Brian Anderson from the University of Newcastle to establish the department, and both arrived in the first half of 1982. The department establishment was six members of staff, three tenured/tenure track and three fixed-term. In addition there was competitive access to School postdoctoral fellowships. In contrast to the generous flow of national competitive funds at the University of Newcastle through the predecessor of the Australian Research Council, the Australian Research Grants Committee (ARGC), all research funds in the first instance had to be provided from the ANU. Nevertheless, in comparison with the internal funds at the University of Newcastle, these funds were much more generous, and there was no impediment caused by the loss of ARGC access. In addition, funds were garnered at times from industry, including Boeing, and Defence, and through a Cooperative Research Centre (CRC for Robust and Adaptive Systems) in which the department was a participant.

John's personal career continued to flourish. He had prestigious fellowships at the University of California, Berkeley, the University of Tokyo and the University of Cambridge, and he spent quite lengthy periods at numerous other institutions in Canada, Mexico, Germany, Singapore and Italy, and a total of more than three years in Hong Kong (Fig. 2). In 1994, he was elected to the Australian Academy of Science, and he received the Vice-Chancellor's award for excellence in teaching in the same year. Later he was elected a Fellow of the Australian Academy of Technological Sciences and Engineering (FTSE).

One of his major research themes, especially during his first decade at ANU, was adaptive control, a notion that can be explained as follows. Control engineers normally model physical systems that have to be controlled—a power generator, an aircraft or whatever—by equations; in these equations, there appear parameters reflecting the underlying physics, for example, mass, air pressure and temperature. Many physical systems also operate in a manner causing these parameters to change: an aircraft is a good example, since the parameters in high-altitude flight are very different from those in low-altitude flight, and its mass changes significantly when fuel is consumed. An adaptive controller is one that learns or tracks these parameter values, explicitly or implicitly, and adjusts its design to compensate for the changes in the system it is controlling, that is, so as to preserve as much as possible the performance being achieved with some nominal or typical parameter values. Evidently, this is a task involving both identification or learning and control, and the simultaneous pursuit of both objectives can often lead to instability. The theoretical challenges in guaranteeing that instability does not occur are formidable; almost as formidable is the task of convincing non-specialists and engineering managers that the proposed solutions will work in real life.

Figure 2. John Moore's 60th birthday symposium in 2001, showing David Hill FAA, FTSE (who had been a student at the University of Newcastle when John was there and in 2001 was a department head in Hong Kong, the symposium location), Gloria Hill, Jan Moore, John Moore and Brian Anderson.

John was one of the major contributors to the development of this subject, with numerous papers, for example, [111], [113], [117], [119], [121], [122], [123], [124], [125], [126], [130], [131], [136], and one of his significant contributions with T. T. Tay [173] was to provide a theoretical basis for stability conclusions when modest parameter changes occurred. This found an important application in the control of Royal Australian Air Force F111 aircraft. The equations describing the operation of military aircraft typically have parameters varying more than those for civilian aircraft, due to the more extreme flight trajectories, and one problem is that a phenomenon known as flutter can be introduced. Flutter refers to the simultaneous occurrence of torsion and bending of the wing, and if unchecked it will lead to the catastrophic loss of a wing. If flutter can be systematically eliminated, the flight envelope of the aircraft can be extended. John's work led to adaptive flutter control, first for Boeing aircraft and subsequently for F111 aircraft.

Near the end of his first decade at ANU, John started increasingly working on problems involving nonlinear systems. This was largely separate from the work on adaptive systems, though at one point the ideas came together with his development of a tool for nonlinear systems like the one he had found for linear systems with T. T. Tay and successfully applied in the F111 context. Given a physical system and an associated controller, both in general nonlinear, it became possible to characterize changes in the controller that should be introduced consequent upon changes in the underlying physical plant, in order to retain desirable performance, including fundamentally closed-loop stability [162], [163], [184].

Round this time too, John started focusing on a signal processing construct called hidden Markov models, and he co-authored a major book in this area in 1995 with Elliott and Agoun [221]. Another theme developed at the same time was the application of gradient descent algorithms, and he completed significant work especially with Helmke [209], [210], [212], [213], [216], including a book on the subject [197]. Among many results, his work showed how differential equations could be used to determine the eigenvalues of large square matrices: the differential equation, which in fact was a matrix ordinary differential equation, was initialized with the matrix to be diagonalized, and then solved forwards in time. Its limiting solution was a diagonal matrix the entries in which were the eigenvalues of the initially given matrix.

The themes of adaptive control and signal processing, hidden Markov models and the associated signal processing, gradient algorithms and nonlinear control continued past 2000, as did some applications work on hand-grasping robots [301]. His interest in robots was perhaps triggered by a six-month sojourn in a robotics laboratory at the University of Tokyo, when he had earlier looked at hand-grasping problems [232].

John wrote few review papers. However, much of his output of papers found its way into books, which therefore are an excellent source from which to obtain an integrated view of what he did.

Applied Projects

Throughout his career, John was involved in applications studies, the outcomes of which were often reflected in reports or patents. The technology areas were highly varied. Apart from the involvement with flight control, he worked on problems of basic oxygen furnace steel-making, irrigation control, hand-grasping robots, panoramic imaging, mixed Global Positioning System (GPS) and Inertial Navigation System (INS) signal processing, and Code Division Multiple Access (CDMA) wireless performance. Such applications problems tended to require recently developed engineering science ideas in control (including modelling) or signal processing for their solution, and John was able to abstract from the detailed technology the scientific underpinnings of the particular problem, and then deliver the necessary science in a usable form.

John's Other Contributions at the Australian National University

During his whole period at ANU, John was a senior academic staff member, and for much of that time held formal managerial roles, including periods as a head of department. The Australian National University in 1982 was much more focused on the international research world than the University of Newcastle had been in 1967, so there was less notion of pioneering in that sense. A different sort of pioneering was however needed. To an extent, a solitary engineering department in a Research School of Physics was a foreign body, and the instinctive reaction of some was negative. Through his own professional performance, easy personality and strength of character, John helped erase those difficulties. He led the successful argument that persuaded the research school to expand into Computer Science. He was one of a number who met a major review committee that caused the school to be renamed Research School of Physical Sciences and Engineering. He played a significant role in designing an undergraduate programme at the ANU, which initially started in the Faculty of Science. And when it came time to separate some groups within the school to form a new Research School of Information Sciences and Engineering, he was a major player, being a department head in both the old and the new structure.

In 2001–2, John assisted in the generation of a proposal for a Centre of Excellence in Information and Communications Technology; this proposal was funded by the Australian Government with an initial grant of over $130M, and John served as a programme leader when National ICT Australia (NICTA) was established.

John was able to achieve these things because, as at Newcastle, he combined great technical strength with qualities of judgment and character and a warm personality that made him hugely respected.

Unsurprisingly, his students and postdocs were aware of his skills and character and valued their experience hugely:

> It was great to work with John. He had an incredible intuition, and a way of challenging me to generalize linear results to the nonlinear arena. I remember spending an afternoon working with him on one aspect. We started with the linear equations and then re-worked them in the nonlinear case. John declared at the end "this will all work in the nonlinear case because I wrote it in red pen!" I was aghast, but he was right. John saw intuitively that the result was correct, but I had to work out all the details – even if it meant finding a new path. It was a great inspiration to work with him. John was also very humble. Although a big name in the control business, he was never arrogant, rather inclusive, friendly and willing to interact with anyone with a good idea. I recall "swimming in his wake" at my first conference, getting to know all the big names that were also personal friends of his. A great opportunity for a fresh PhD student! I remember one young professor coming hiking with us after the conference and asking me "Is that THE John Moore?". He couldn't believe that John was such a regular guy. I will always remember John for his openness, his energy and enthusiasm and that fantastic intuition for what would turn out to be right, what was a great idea. I will be forever thankful for the opportunity to work with and learn from him for a short time. (Andrew Paice)

And another:

> John was a central part of my life for nearly a decade when I was a student and a postdoc. As a supervisor I remember his intuitive genius and

Figure 3. John Moore was a keen skier, and while spending six months in Washington State in the USA on a sabbatical leave he sampled the skiing opportunities that were on offer. The date and location of the picture are unknown.

ability to grasp the essence of a problem and see the nature of the solution almost immediately. He was always willing to try new research directions and new ideas, even if he had little background in the area. As I have become more senior I realise what a rare gift this is. He had an inner confidence that given time he would make significant contributions, even if his initial ideas were naive. As a consequence, I believe his scientific legacy contains the germs of many fundamental paradigm changes across a whole range of fields. More important than John's scientific contribution was his personal touch, the respect, morality and self-belief that he engendered in staff and students. He was always a sympathetic supervisor and viewed research as a collaborative venture between colleagues and friends. His inclusiveness and openness has rested with me throughout my career and I count myself extremely lucky to have had the chance to spend significant time with John. (Rob Mahony)

Private Life

John did not just live to work, but worked in order that he might live a rich life. Intellectually, he at times read closely in psychology and general science, and he followed politics quite keenly. Physically, he enjoyed a series of thrill if not high-thrill sports. Thus in his 20s or 30s, he was a hang glider. He was a skier for most of his life (Fig. 3), a sailboard rider for two decades, and a bushwalker for virtually all his adulthood. Bushwalking was far more than climbing Canberra's Mount Ainslie on a Sunday afternoon, and included hiking in the Patagonian Andes. He always seemed to manage well the family/work balance, not always a straightforward task for those who are talented and highly motivated in some scientific field.

Reflecting this balance, he had decided to retire simultaneously with his wife Jan. In fact, she retired before him and engaged in several activities that were new for the couple, and that John was not able fully to share. Accordingly, he decided also to retire, and, after ensuring that his research students completed their degrees, he retired in 2006. In 2007 he was diagnosed with kidney cancer, which at the time of its discovery was found to have already spread. For most of the course of his illness, though more or less continuously on treatment, he enjoyed a surprisingly high quality of life and maintained a high level of cardiovascular fitness, especially through bicycle riding. Upon the initial diagnosis, he started studying all he could about the disease, corresponding with researchers in the process, and during the course of the disease tried thirteen different treatment options, many experimental, from around the world (including the USA, China, the Philippines and India, as well as Australia). It was his scientific approach to the disease and willingness to approach researchers running trials that perhaps improved his chances of selection. He also became a major contributor to a kidney-cancer support group, whose leader's remarks about John bear quoting: 'One of the most medically adventurous members this list has known, John chose his treatment options carefully from around the world including unusual and innovative ones that had us following his progress with interest. We will certainly miss John's kind, knowledgeable, cheerful and inquisitive presence.'

These last four adjectives kind, knowledgeable, cheerful and inquisitive are just as descriptive of John's relations with colleagues and students, and these qualities added immeasurably in their eyes to his status as a researcher. One might add too that he was unpretentious, and modest in his life style.

He lived in Canberra till his death on 19 January 2013.

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