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Arthur James McComb 1936–2017

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Professor Arthur McComb conducted pioneer research on the occurrence and mode of action of the plant growth hormones gibberellins for fifteen years. He then applied his experimental skills and physiological knowledge to develop a whole ecosystem approach to the study of aquatic systems. He was passionate in wanting to improve the state of environmental management, based on rational, logical and well-founded biological principles. He and his team focused primarily on the mechanisms controlling plant growth and productivity in aquatic environments, and especially the effects of nutrient enrichment and its consequences, eutrophication. He became a leader in nutrient analysis of water systems, with innovations in how to determine nutrient pathways into waterways and strategies for fixing these issues. This important research has informed the long-term management of several important aquatic systems in Western Australia: the Blackwood River Estuary, the Peel Harvey Estuary, and the protection of seagrasses in Shark Bay, the Swan River and Cockburn Sound. Arthur McComb had a seminal influence on a generation of researchers. Thirty-nine students completed their higher degrees under his supervision and they are spread internationally and throughout Australia in universities, state government departments and consulting firms, confirming his influence on driving our understanding and management of marine, estuarine and freshwater systems.

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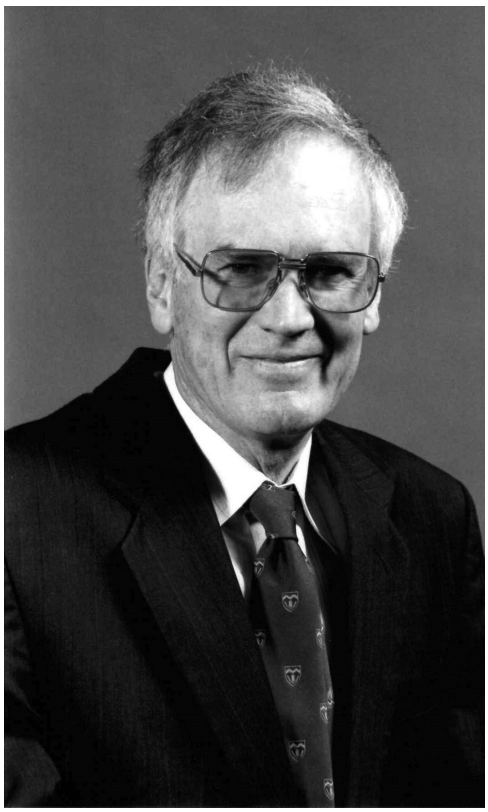
Early Days in Melbourne

Melbourne, Victoria, was Arthur's boyhood home. Both his grandparents had convicts in their ancestry. One, William Richardson, was transported to Australia in 1803 in HMS *Calcutta* and was a member of the first colony in Victoria at Sullivan's Cove. The site proved intractable, with infertile sandy soil and an inadequate water supply so after two years the whole party transferred to the fledgling colony of Hobart. Eventually Richardson obtained his ticket of leave and married another English convict, Elizabeth Winrow. Their daughter, Grace Richardson married Thomas McComb, a ship's carpenter and former soldier, who came from Greenoch, near Glascow. They became among the first settlers of Frankston, and their family included Arthur's grandfather John McComb. His mother's maiden name was Gorrie, and her antecedents came from the Orkney Isles. The family lived near Kirkwell on a farm too small to support all the sons, one of whom, James Gorrie and his wife emigrated to Australia, setting up a draper's shop in Port Fairy in the mid-1850s.



Arthur James McComb was born in Melbourne on 9 December 1936. His father had served in World War 1 in the AIF 3rd Field Ambulance as a stretcher-bearer, an experience that left him with an anti-violence life view that was also upheld by Arthur. After the war he worked as an auditor for the Victorian railways. Arthur's mother, Gladys Mary, trained as an opera singer, but in line with the conventions of the time, became a housewife after her marriage. Arthur and his brother Ray, two years his senior, grew up heavily involved in the Methodist youth club and seemingly spent most of their time working on old cars at their home in East Malvern, including a 1924 Fiat 501, a 1937 Riley Falcon and a 1940s Vauxhall.

At Melbourne Boys High School, Mr Fitridge, Arthur's biology teacher, noted his excellent drawings and large collection of beautifully pinned and labelled insects, and suggested he submit the collection to a Science Talent Search. He was awarded the third prize of £25 and this together with money earned serving petrol on weekends at garages enabled purchase of a 1927 Armstrong Siddeley. This was a challenging car, hard to start and difficult to drive but it provided the means of many enjoyable trips and adventures.

Learning that the money for the prize had been made available to the science teachers by Imperial Chemical Industries (ICI), and

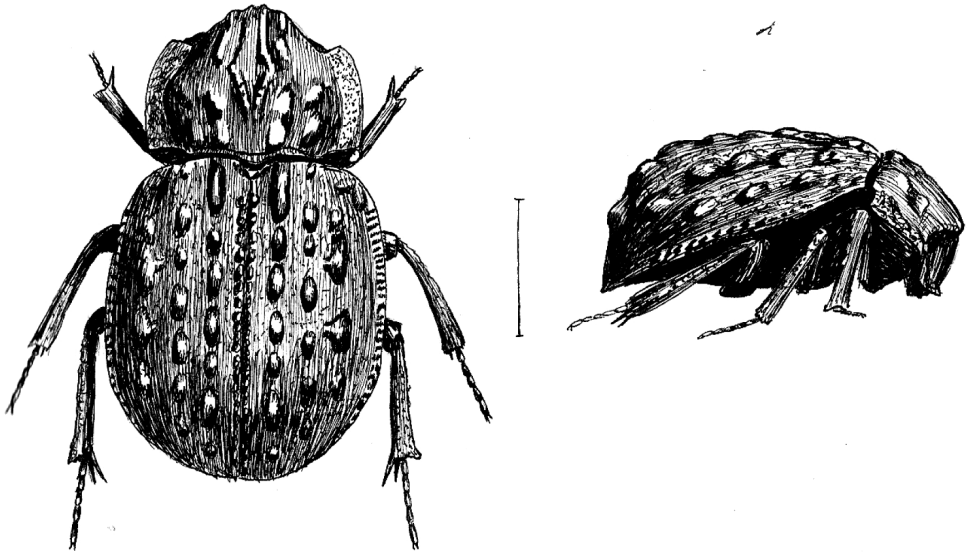


Figure 1. *Trox tatei*. A beetle drawing by Arthur McComb as an undergraduate.

being a conscientious lad, he wrote a letter of thanks to the general manager. This had an unexpected bearing on his future career. He received a prompt reply, pointing out that the company was pleased to encourage students to take up careers in science, and further, they were about to build a biological research station, and might be able to offer vacation employment. So it was that Arthur spent two university long vacations working at the new ICIANZ Merrindale biological research station near Croydon, on the outskirts of Melbourne. He was mainly involved in laboratory, glasshouse and field work on the herbicides 2,4-D, 2,4,5-T and MCPA, all structural and functional analogues of the naturally occurring plant growth hormone auxins, such as indole-acetic acid.

Arthur majored in botany and zoology for his BSc at the University of Melbourne, always intending to become an entomologist (Fig. 1), but in his final year as an undergraduate in botany he was required to do a small research project on plants, and he decided to work on species of rush (Junaceae), which though native, had become weeds of pasture. This sparked off a long-standing interest in wetland plants. He was finally won over to botany by his holiday jobs at ICI and the brilliance of Denis Carr, then reader in botany at the University of Melbourne. Denis remained an inspiration and role model in many ways except for his irascible manner of dealing with people who disagreed with him.

When Arthur started his Masters degree, plant physiologists were being persuaded by increasing evidence that auxins were not the only plant growth hormones. The gibberellins had only just attracted attention in the western world, despite their discovery in 1927 by Japanese plant pathologists working in Taiwan. Because of their spectacular effects on plants, where they interact with plant genotype and environmental factors such as photoperiod, their occurrence and mechanism of action were of particular interest. The ICI group began work on gibberellins and through his contacts Arthur obtained a culture of the fungus used as a source of gibberellin. He was able to isolate the chemical, using paper chromatography as the final step. His first publication on gibberellins was in *Die Naturwissenschaften*[1] with Denis Carr, and another student, Lynette Osborne. The paper described how treatment of a rosette plant with gibberellic acid (GA) led to stem elongation, and subsequently (under long-day conditions), to flowering. Soon after that he made an extract from pea shoots (Fig. 2) using essentially the same method as that used for isolating GA from fungal cultures. The compounds separated by paper chromatography were then tested for biological activity using a biological assay based on dwarf pea seedlings. This provided the first evidence that gibberellin-like compounds occur naturally in higher plants and he and Denis published the results in a letter to *Nature*.[2] Arthur was awarded a MSc with honours in 1959.

Arthur was successfully nominated by the University of Melbourne to become an overseas scholar of the Royal Commission for the Exhibition of 1851. This funded him to study for his PhD from the University of Cambridge where he was affiliated with St Johns College. His parents were less than enthusiastic and, unused to the perambulations of scientists, contacted Denis Carr to ask 'Is this entirely necessary?' They were assured that it was. The trip to the UK in *Strathmore*, together with several other Australian students travelling to various British universities, took six weeks and several friendships were forged on board.

The School of Botany, Cambridge University

During his time at ICI Arthur had met Martin Canny and admired his meticulous experimentation. Martin was subsequently appointed to Cambridge University and supervised Arthur's PhD. Martin did far more for his students than just supervise their research. He took them on excursions and urged them to take the opportunity to experience the history and culture of Cambridge and to travel widely. Arthur's visits to museums, markets and antique shops resulted in a life-long interest in Persian carpets, old books, antique clocks and Chinese porcelain. His love of old cars continued and he gained permission from the 'Proctor of Motor Vehicles' of his college to own a car. With his scholarship paid two quarters in advance, he set off to London and to everyone's astonishment purchased a

Figure 2. Arthur McComb (1958) with pea plants showing the effect of gibberellin on the growth of dwarf peas.

Rolls Royce. Optimistically he went to the largest Rolls Royce dealership in London, Jack Barclay's in Berkeley Square. On telling them he had about £400 to spend he was advised to look for a prewar model at Paddon Bros, Knightsbridge. There he found for £375, a 1935 20/25 Rolls Royce with only 65,000 miles on the odometer and needing just a little mechanical work. A few weeks later he picked up the car in mid-morning in London, and, knowing that England was only about the size of Victoria, thought he could easily reach the Lake District by late afternoon. He had enrolled there in a course by the British Council for overseas students wanting to experience an English Christmas. He eventually arrived in Keswick very late at night in darkness and fog, but had a wonderful introduction to an English Christmas, with a midnight carol service in the local medieval church, a display of hand bell ringing, a beagling meet, a hoar frost, a visit to Wordsworth's cottage, and fine Christmas fare. During his three years in the UK the Rolls provided transport for him and his friends to undertake trips around England and Scotland, and with the confidence of youth, even through the daunting traffic of Paris and other European capitals.

At the Cambridge Botany School he continued research on gibberellins and was able to synthesize C_{14}-labelled gibberellic acid by feeding the *Gibberella* fungus with labelled acetate.[3] The labelled gibberellic acid was used to examine its translocation and stability in higher plants. He also published papers on the possibility that gibberellin might become bound on protein as legume seeds mature[4] and that gibberellin has an effect on plant growth movement.[5] It is also interesting that Martin gave his student sole authorship of papers whereas most supervisors then and now would consider joint authorship completely justifiable. It clearly made an impression. Arthur was always scrupulous about listing the authors of a paper according to their contribution.

Although he enjoyed his time in Cambridge Arthur was very keen to return to Australia and was offered a position at CSIRO Plant Industry in Canberra, or a lectureship in the Botany Department of the University of Western Australia (UWA). He decided on an academic position and he and the Rolls arrived in Perth by ship in time for Arthur to prepare lectures for the start of the 1963 academic year.

The University of Western Australia

It was a good time to join an Australian university, with increasing student numbers and a Federal Government enthusiastic about universities. Funds for research were available, and a new Commonwealth funding scheme had been set up, administered by the Australian Research Grants Committee (ARGC), the forerunner of the Australian Research Council (ARC). Arthur received a grant in the first round of these grants and this helped set him up to continue his research and begin to attract the first of a long list of talented research students.

Working with Arthur, Bob Jennings discovered that algae, like certain fungi, produced gibberellin- like compounds,[6] and that algae also synthesized cytokinins, another group of plant hormones that have been implicated in the control of cell division and senescence. Subsequently he became professor of photobiology at the University of Milan.

Bill Broughton and Arthur followed up the work on the metabolic changes in expanding internodes of pea plants treated with GA. The marked increase in the synthesis of cell wall material, was found to be associated with an increase in protein and RNA synthesis and a change in the pattern of different enzymes present, suggesting a fundamental change in differentiation.[7] Bill Broughton became professor of higher plant molecular biology at the University of Geneva.

Another program concerned the occurrence and function of plant resins. This came about because colleagues in the Department of Organic Chemistry at the University of Western Australia had found that the resins of certain arid-zone plants contain chemicals so closely related to gibberellic acid that test plants responded to the resin compounds just as if they had been treated with gibberellin. It seemed logical to use resin synthesis in these plants to follow the synthetic pathways. Bernie Dell and Arthur studied the formation and secretion of these resins, using tissue culture, fine structure, and C_{14}-labelled mevalonic acid (a terpenoid precursor) and after several publications in this area were invited to write a review on the formation and possible function of resins, for *Advances in Botanical Research*.[8] Bernie Dell joined Murdoch University where he became a Professor of Plant Science. Byron Lamont who worked with Arthur on proteoid (cluster) roots became a Professor of Biology at Curtin University.

In 1969, while on study leave at the Atomic Energy Commission Plant Research Laboratories of Michigan State University Arthur and his wife Jen, working with American colleagues, found that the

increase in RNA induced by gibberellin treatment was affected by an increase in RNA polymerase activity, without a detectable increase in the amount of DNA template available for transcription.[9] They also explored the possibility that the phenotypic control of growth rate in tall and dwarf strains of pea seedlings is graft transmissible. It was an interesting time to be in America with student protests and the country tearing itself apart over the Vietnam War and civil rights. The McCombs were glad to return to Australia where they purchased a ramshackle old house built in 1923 in Kalamunda, and Arthur spent many happy weekends renovating the house and establishing the garden.

Although gibberellin research still held much interest, by 1976 it had become increasingly clear that further progress at an international level was going to be dominated by advanced organic chemistry on the one hand, and biochemical studies of gene action on the other. It required the latest, expensive equipment not easy to obtain by an individual working in Perth. Further, more students were asking for projects on ecology, and conservation was becoming an important issue. After a study leave in Leicester working in Herbert Street's laboratory on the effect of plant growth hormone in plant tissue culture, Arthur made the decision to discontinue work on plant hormones and concentrate wholly on environment aspects of plant physiology.

His first ecological project involved John Mott and they studied the autecology of annual plants in semi-arid area of the State (now the site of the Square Kilometre Array). They collaborated with Stephen Davies (CSIRO) who was interested in the migration of kangaroos, and knew the growth of annual plants to be a major controlling factor in this behaviour. In a sense this was an extension of Arthur's work on rosette plants because annuals like the everlastings are rosette plants. He and John studied the factors controlling flowering, germination and survival in seed banks.[10]

Arthur also followed up his long-standing interest in wetlands—starting with a time-course study of the nutrients and phytoplankton in Lake Joondalup,[11] and moving on to a study of the Blackwood River. There had been a proposal to mine the area for mineral sand, and because so little was known about the system the Environmental Protection Authority sponsored a major study on the fisheries, hydrology, and social aspects of the system. It was led by Ernest Hodgkin and included a PhD study by Bob Congdon on aspects of the plant ecology of the area, the productivity of the submerged aquatic *Ruppia maritima* and how this might be affected by turbidity, and the productivity of the extensive salt marshes of the estuary, dominated by the rush *Juncus maritimus*.[12]

After the Blackwood River Study, Arthur was invited by the Department of Conservation and Environment to participate in a study of Cockburn Sound led by Graeme Chittleborough of that department. There was concern about increasing blooms of phytoplankton, and about the loss of seagrass meadows near the recently established industrial area on the shore of the sound. PhD student Marion Cambridge linked the loss of seagrass with the establishment of industry along the shore, and showed that the loss was due to the increased growth of epiphytic algae on the leaf surfaces.[13] Tony Chiffings found that water, enriched by nutrients arising from industry, and carrying increased loads of phytoplankton moved over the area from which seagrasses had been lost.[14] Part of the nutrient enrichment was attributed to a contribution from the discharge of treated wastewater derived from sewage and this was set to increase with the expansion of the population of Perth. As a result

Figure 3. Arthur McComb in the Murdoch University wetlands laboratory (1990). Photo: Brian Richards.

of this study, the state government decided to expend some $40 million in re-routing treated sewage effluent to a more appropriate discharge site to the south, while industry responded by reducing levels of nutrient discharge into the Sound. These measures have led to improved water quality.

It was at about this time that Arthur discovered, much to his disappointment, that an underlying heart problem was to prevent him joining his colleagues in scuba diving in the underwater field work.

A new project with Ernest Hodgkin followed on the Peel/Harvey Estuarine System. Here there was a major eutrophication problem characterized by masses of rotting macroalgae on the beaches of Peel Inlet, and intolerable blooms of the blue-green 'alga'—the cyanobacterium *Nodularia*—in Harvey Estuary. The nutrient analysis facilities (Fig. 3) that he had built up during the earlier projects were expanded to cope with the large number of nutrient analyses needed and aspects of this large study provided the basis for several PhD projects. David Gordon worked on the alga *Cladophora*.[15] Rod Lukatelich unravelled the transfer of nutrients from river water into diatom blooms, the zooplankton, then onto sediments and their release to fuel *Nodularia* blooms. Paul Lavery documented the decay of banks of macroalgae, and the recycling of their nutrients in the estuary.[16] Their results and ideas were fed into the larger program that involved other scientists, representatives from government departments and industry, and members of the wider community. Arthur was always careful to design projects so that the contributions of individual research students could be disentangled from the complexities of a major study. There were

many exciting workshops and seminars during the study, and Arthur once commented that doing research and presenting meaningful results to an interested public gave him more satisfaction than a paper in a prestigious journal.

While this work was unfolding, Arthur and Jorg Imberger at UWA wrestled with the problems of sustaining research programs without continuity of funding for postdoctoral fellows and highly qualified technical staff. Arthur had substantial funding from the Department of Conservation and Environment for the Peel/Harvey and Cockburn Sound studies, and Jorg was very well funded for work on physical processes in reservoirs. With support from various agencies, they were able to set up a Centre for Water Research (CWR) at UWA with a guarantee of secure funding for six years. The CWR became important in the scientific endeavours of the state.

Murdoch University

In 1989, Arthur was delighted to be appointed Professor of Environmental Science at Murdoch University. Arthur felt at home at Murdoch where interactions between research, industry and the community were highly valued. He moved across with his large team of research colleagues and went on to grow environmental science at Murdoch, and champion environmental issues.

Continued work on the Peel/Harvey confirmed the cause of eutrophication to be nutrients derived from the river systems draining sandy catchments used for agriculture. Collaborative work with staff from DCE, the Centre for Resource and Environmental Studies in Canberra (CRES), the Western Australian Department of Agriculture, and the Department of Soil Science and Plant Nutrition at the University of Western Australia, supported the conclusion that altered procedures for applying fertilizer to the land surface of the catchment would improve the estuary,[17] but that a dramatic improvement in the short-term could only be achieved by dredging a new opening to the ocean. The proposed opening, the Dawesville Channel, was constructed for some $38M in 1994 after extensive environmental scrutiny, and led to an immediate improvement in water quality, in that there have been no further *Nodulari*a blooms in the Harvey, and a reduction in macroalgal biomass.

Work on seagrasses expanded to include further aspects of seagrass biology in other geographic areas such as the Swan/Canning estuary, Shark Bay, Rottnest Island, the Dampier Archipelago and Wilson Inlet in collaboration with Di Walker,[18] Tony Larkum,[19] Karen Hilman,[20] John Kuo,[21] Eric Paling[22] and others, led to several key publications in these areas. He became a member of Cockburn Cement's Environmental Management Advisory Board that reported on the impacts on seagrass of dredging for shellsand (necessary for lime production), from banks to the north of the Sound and on work with Eric Paling on seagrass transplantation.

He was also involved in the establishment and management of the Capel Wetlands Centre. This lies in an area that has been subjected to mining for mineral sands, leaving an undulating landscape in sandy soil that intersected the water table. The company, then RGC Mineral Sands (now Iluka Resources), was attracted by the concept of establishing a centre to carry out relevant research, and eventually establish a self-sustaining ecosystem that would support water bird populations. The research with collaborators such as Jane Chambers involved work on water quality, food webs and establishment of wetland plants.[23]

Arthur's interests extended to wetland modelling, the management of urban lakes,[24] the effectiveness of ecological impacts of mosquito control methods, effects of drying and re-wetting of wetland sediments, the role of microbial biomass in controlling transfer of nutrients from decomposing leaf litter to groundwater and wetlands,[25] and improving methods for disentangling the microbial contribution to soil nitrogen and phosphorus compartments as well as to more diverse topics such as proteoid roots, *Phytophthora*, and root mats in caves.[26] His last PhD student, Alan Hill worked on Aboriginal use of wetlands.

Arthur became increasingly unwell with heart disease but expected the problem to be fixed with a heart bypass operation. However, he had a disastrous stroke and heart attack during the operation in 1995. He was initially left unable to speak, read, or walk. Six months of rehabilitation at Shenton Park Hospital and many more months of rehabilitation at home followed. Surprisingly, he could still play the accordion and touch-type, despite the fact he lost the ability to draw or drive a car. As part of his rehabilitation he wrote a little booklet entitled *Stroke Recovery, a Team Effort*, documenting the recovery to encourage those in a similar situation. His determination amazed everyone and he eventually returned to work part time at Murdoch for two years. He was always tremendously grateful for the encouragement and support he received from his friends and colleagues and from Murdoch University during this period. It was clear, however, that he could no longer cope with the demands of the administration of a university department as well as the research. He retired at the age of sixty but remained active at the university becoming an Emeritus Professor and Senior Scholar in Residence in Environmental Science.

Before retirement Arthur had helped draw up a successful proposal for a research centre in organic waste management, under the Western Australian state government's 'Centres of Research Excellence' Scheme and was chair of its Board of Management. Staff associated with the Centre were involved in research on municipal waste composting, land application of organic waste, anaerobic and aerobic digestion, and conflict resolution in the siting of waste facilities. After the departure of the initial director, Arthur took over this role. Waste management might initially appear to be quite a departure from his previous research, and field trips were considerably less scenic than those to lakes and wetlands. However, as Arthur put it, 'When a large amount of organic material becomes available in the environment, much the same microbial processes are set in train, utilising the material as a source of energy and nutrients, whether that material be sewage sludge, lawn clippings, detritus in a seagrass meadow, beach wrack, the sediment surface in a wetland, or the gut of a dugong'.

On his 75th birthday Arthur 'retired' for the second time, and Murdoch University conducted a congratulatory seminar with Jenny Davis as the main speaker. A broken hip in 2009 eventually confined him to a wheelchair, but with Jen he was still able to enjoy travels around Australia and spending time in Denmark, Western Australia. His health deteriorated and he died at home on 8 October 2017. Several obituaries have been published.[27]

Family life

Arthur met his future wife Jen Chessell when he arrived in the UWA Botany Department. His earliest ecological work was done with Jen, as during their courtship they collaborated in documenting the wetland vegetation of Loch McNess in the Yanchep National Park.[28] The snakes, mud, mosquitoes and blister bush of the fens were enough to convince Jen that plant genetics was an easier research

Figure 4. Arthur and family in the 1935 Rolls Royce, Perth 1991. Photo: Peter Whyte.

option. They married in 1966, celebrating their golden wedding anniversary in 2016. Jen did her PhD in plant cytogenetics, became a post-doctoral fellow in plant breeding in Agriculture, and then a foundation member of staff at Murdoch University, where she is now an Emeritus Professor. They have two children, David born in Perth in 1974 and Christine born during the study leave in Leicester in 1976. David and his wife Jennie presented them with a grandson, Nils, in 2015. The much-travelled 1935 Rolls Royce remains in the family (Fig. 4).

Publications

Arthur wrote or edited nine books and conference proceedings and some 168 refereed papers. Two important books he edited and wrote with Sam Lake were *The Conservation of Australian Wetlands*[29] for fellow scientists, and *Australian Wetlands*[30] for the general public, showing the authors' enjoyment of informing a wider audience of the importance of scientific research. A full list of publications is available in the Supplementary Material.

Awards and Community Service

Arthur received many prestigious prizes and awards in recognition of his contributions to the understanding and management of marine, estuarine and freshwater systems. He was a Fellow of the United Kingdom Institute of Biology and was awarded the Hilary Jolly Award of the Australian Society for Limnology in 1991, the Kelvin Medal of the Royal Society of Western Australia in 1997, the Prime Minister's Centenary of Federation Medal for Environmental Science in 2001 and the Silver Jubilee Award from the Australian Marine Sciences Association in 2002. In 2007, he was the first person to receive a DSc from Murdoch University. He was elected a Fellow of the Australian Academy of Science in 1996 and from 1996 to 2000, served on the Academy's Sectional Committee on Plant and Microbial Sciences.

Within state government, Arthur served as chair of the National Parks and Nature Conservation Authority, the Lands and Forest Commission, the Herdsman Lake Wildlife Centre and as a member of the Life Sciences Panel of the Cooperative Research Centre's Committee. He was on the organizing committee for various conferences and held office in several professional societies. His sharp mind, amiable nature, and ability to get even warring tribes to communicate, made him popular as a chair, coordinator of large complex projects, and for dispute resolution.

Arthur's Own Summary of His Research

In his speech on the occasion of his 75th birthday Arthur reflected his research career:

> My research has shifted from essentially academic research in plant physiology to much more applied research. This shift has been driven by a changing funding environment, the shifting interests of research students, my perceptions of areas which might offer employment opportunities for graduates, and the needs of providers of research funding. My career has throughout it has been driven by the scientific principles of carefully defining tasks, framing and testing hypotheses, and publishing results in the refereed scientific literature. It is a privilege to have enjoyed the excitement of making scientific discoveries, and of participating in work which has had practical outcomes and equipped students for their future careers. The path I trod might suggest that I carefully mapped this out and moved along it with confidence. Nothing could be further from the truth: I

have been unashamedly opportunistic, moving into new areas when a path has opened up, often because of the interests of research students, the vagaries of funding, and the constraints of academia. I have been immensely fortunate to have had such a succession of talented research students and collaborators.

A list of Arthur's postgraduate students is given in the Supplementary Material.

Conflicts of Interest

The author was married to Arthur for over 50 years, which may have influenced her opinions.

Acknowledgements

I thank Dr Don Gaff, Prof Di Walker, Dr Jane Chambers and Ms Margaret Papst for their contributions and suggestions. I was also able to draw upon the account of his research that Arthur submitted with his DSc.

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