

Recent Advances in Animal Nutrition – Australia: people and circumstances shaping this symposium's successful first 50 years

John V. Nolan 

Emeritus Professor, University of New England, Armidale, NSW 2350, Australia. Email: jnolan@une.edu.au

Abstract. The symposium ‘Recent Advances in Animal Nutrition – Australia’ (RA) was instigated at the University of New England (UNE) in the early 1970s. In the 1950s and 1960s, under the visionary leadership of Professor G. L. (Bill) McClymont, a talented group of young biochemists and nutritionists was recruited to become the Department of Biochemistry and Nutrition at UNE and quickly developed a strong reputation for nutritional research on ruminant and monogastric animals. Its members were keen to share their findings with relevant industry representatives and to learn about the major industry challenges. The idea for RA emerged ~1970 when Drs Robin Cumming and David Farrell saw the opportunity for regular RA schools, bringing invited experts from Australia or overseas to interact with UNE staff, post-graduate students and representatives of the monogastric and ruminant livestock industries. The first RA school was probably held in 1974. Aided by flexible working arrangements at UNE, David Farrell was able to champion further RA meetings that were held successfully about every 2 years. However, ~1990, the federal Education Minister John Dawkins began a process of amalgamating Australian higher-education institutions that produced detrimental administrative and financial ramifications for UNE and drained staff morale. After the 1993 meeting, Professor David Farrell left UNE, followed soon afterwards by Professor Ron Leng. The future of RA was at a crossroads; its funding and organisation needed overhauling to enable it to survive. A second, more formal phase of RA meetings (13 in all; 1995–2021), was instigated within a newly formed Department of Animal Science at UNE. The meetings became more formalised and even more financially dependent on industry support and sponsorship; meetings were planned by larger organising committees. Soon, papers were being formally refereed and the scope for provocative speculation of the type promoted at earlier meetings was somewhat curtailed in favour of scientific rigour. Organisers experimented with changed meeting dates, formats and venues at UNE, cumulating with a contentious decision to hold this meeting away from UNE. Despite its challenges, RA has grown in stature over 47 years from the small, informal schools of the early 1970s, to become Australia's leading animal nutrition symposium.

Keywords: ruminants, pigs, poultry, human nutrition, aquaculture.

Received 20 April 2021, accepted 1 June 2021, published online 23 December 2021



Emeritus Professor John Nolan has been associated with the ‘Recent Advances in Animal Nutrition – Australia’ symposium (RA) since its inception in the early 1970s. His connection with the University of New England (UNE) pre-dates RA and spans nearly 60 years from when he enrolled in the Bachelor of Rural Science degree program in 1962. His mentors in the Department of Biochemistry and Nutrition at UNE in the 1960s included people who played a major role in the instigation of RA, Professors G. L. (Bill) McClymont, Frank Annison, Rob Cumming and David Farrell. During John's PhD studies under the supervision of Ron Leng, he pioneered ^{15}N tracer dilution methods as a means of quantifying nitrogen kinetics and protein conservation in ruminant animals. His expertise in animal nutrition led to international consultancies with FAO, IAEA and ACIAR in developing countries and afforded many opportunities for networking. After about 15 years of full-time postdoctoral research, John joined the staff in the Department of Biochemistry, Microbiology and Nutrition at UNE, the original home of RA. During the next 15 years, his livestock nutrition research extended to include feeding behaviour (choice feeding and feed aversion) in ruminants and also poultry. Later, John served for 10 years as Professor of Animal Nutrition in the School of Environmental and Rural Science at UNE. Since his retirement in 2011, he has maintained an active role in research and postgraduate student supervision and has added to his several hundred refereed reviews and research reports that have contributed to his current Hirsch index of 47. Over the years, John has contributed numerous reviews to RA and his postgraduate students have always been encouraged to present their most-recent work at the RA symposia.

Introduction

This history of ‘Recent Advances in Animal nutrition – Australia’ (RA) explains how animal nutrition ‘schools’ came into being at the University of New England (UNE) in the early 1970s and developed into a flagship symposium in the following half-century. The symposium was originally simply named ‘Recent Advances in Animal Nutrition’ but, by 1980, the regular meetings were gaining international recognition. The organisers of the identically named animal nutrition conference at the University of Nottingham, instigated in 1967, felt they had first claim to this title and asked its Australian counterpart to change its name. An amended title ‘Recent Advances in Animal Nutrition in Australia’ was adopted. A further amendment occurred inadvertently in 1993 when ‘Recent Advances in Animal Nutrition – Australia’ was used in the promotional material. This change, though minor, did create some library cataloging issues.

There have been two distinct epochs for RA. During the first 20 years, David Farrell was the principal organiser during a time when there was a good deal of flexibility in working arrangements at universities. The second period (1993 to the present) was one in which there was much less flexibility in academic and research organisations. The organising committees could expect less support from UNE resources and were more dependent on financial contributions from industry sponsors. Also, the nature of livestock research was changing; research problems were becoming more multi-faceted and were therefore tackled by multi-disciplinary groups that often spanned several research organisations.

Since the inception of RA, many novel nutritional concepts and new research data have been aired by invited speakers and other attendees. I have not been able to do justice to the more than 400 invited papers presented at RA meetings but some of the presenters have been cited to highlight visitors from overseas and the variety of material presented over the years. It has not been my intention to imply greater merit to particular papers over others not discussed, but rather to give the reader a sense of the varied scientific issues and developments that have been canvassed at RA symposia. The task of compiling this history has been challenging; there will inevitably be errors and omissions, for which I take full responsibility.

In its first 47 years, RA has grown in stature from the small, informal schools of the early 1970s to become Australia’s leading animal nutrition symposium, attracting research scientists, nutritional experts and industry representatives from around the world. It seems inevitable that the symposium will continue to be a peak venue for livestock nutritionists to exchange, discuss and act on the latest research findings. However, there will always be a need for adjustments and improvements; in a short concluding section, I have briefly considered existential issues that may confront animal nutritionists in general, and the organisers of future RA meetings in particular.

Concept and formative years

The 2021 meeting is our 26th gathering. Many attendees will not have been born when the first meeting was held nearly half

a century ago. Nevertheless, RA has some very loyal elders who have attended the majority of the meetings for nearly 50 years; examples are Tony Edwards, Roger Campbell, John McLeish and myself. What was the formula that has engendered this patronage, and the success and longevity of this symposium?

Historical perspective

The initiators of the first RA meetings in Australia were members of the young Rural Science Department that had been established at the University of New England (UNE) in the mid-1950s by Professor G. L. (Bill) McClymont AO (Fig. 1), a veterinarian, nutritional scientist and redoubtable educationalist (McClymont 1996; Ryan 2007; Bell 2020).

The Rural Science undergraduate degree program that Bill developed at UNE in the late 1950s was the first of its kind to integrate animal husbandry, agronomy, soil science, economics and other disciplines into the field of livestock and agricultural production. Bill developed an international reputation for his eco-system model of agriculture that also summarised the Rural Science curriculum.

During the 1960s, UNE was a young rural university without the traditions and boundaries of older universities, and Bill McClymont was a visionary in the right place at the right time. Bill recruited talented young biochemists and nutritionists such as Frank Annison and Derek Lindsay from England and Robin (Rob) Cumming from South Africa and, later, Ron Leng, who together established a

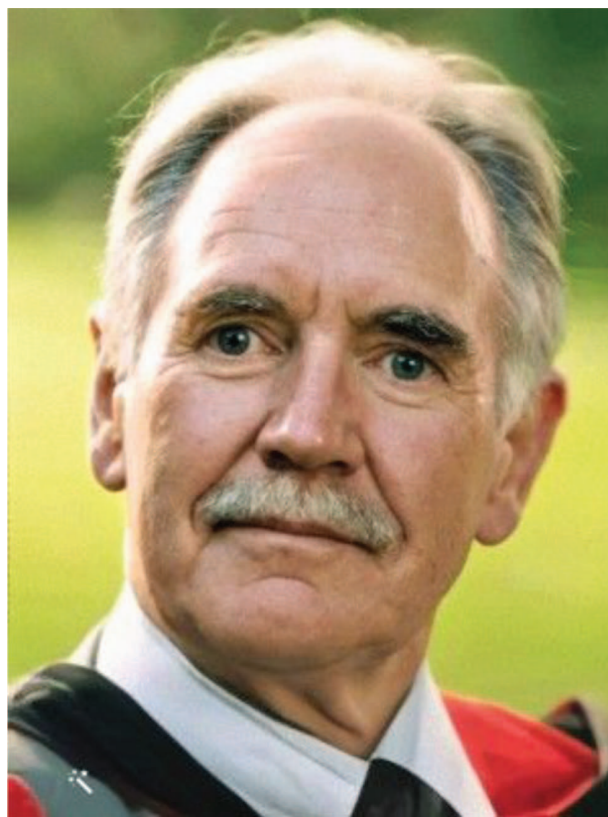


Fig. 1. Professor G. L. (Bill) McClymont.

strong Department of Biochemistry and Nutrition at UNE. Ron Leng came from Yorkshire in England as a demonstrator; he completed his PhD with Frank Annison, then joined the staff as a Lecturer in 1963. He was soon himself supervising PhD students (Mario Cocimano, Robert White, John Steel, Geoffrey Judson, David Farrell and John Nolan) and building a group of scientists with a formidable reputation in ruminant nutrition. Mentored by McClymont and Leng, all of these scientists were encouraged to challenge the then-current frontiers of knowledge in their own disciplinary areas. After trying various work options in several countries, Irishman David Farrell had settled into academia at UNE as a mature-age PhD student in 1967. His principal supervisor was Dr John Corbett at the CSIRO Chiswick Research Station near Armidale. (At this time, CSIRO also had offices in the Rural Science building on the UNE campus.) After completing his PhD, David changed paths and focussed on monogastric animal nutrition.

The memories of people from that era who are still with us do not provide a definitive account of how RA came about; however, certain elements that facilitated its conception can be identified. Bill McClymont believed that agricultural knowledge held at UNE should be shared with the community and, in the early 1960s, was preparing the ground for this to happen. As Head of the Department of Rural Science and in conjunction with the Department of Agricultural Economics and Farm Management, Bill fostered the formation of community centres for agricultural education around the New England region, modelled on similar examples from universities in the United States. These centres were financially independent and so did not answer to the central administration of the UNE. McClymont and Cumming established one such centre, namely, the Poultry Research Fund Group, at the Tamworth Adult Education Centre. The group first met 1 July 1963 and went on to demonstrate how successful links could be forged among scientists, farm managers and commercial partners, for mutual benefit. The impacts of Cumming and McClymont were recognised by the poultry industry with the Australian Poultry Award in 1966 and 1968 respectively. Importantly, the favourable outcomes of the interactions between the University and the Tamworth poultry industry resulted in the formation of a fund for poultry research at UNE to which farmers contributed a voluntary levy. This was a successful model for research funding that became a blueprint for the formation of national funding bodies for both the chicken meat and egg industries; the industry levy was matched by funding from the government. (These funding bodies subsequently became part of the Rural Industries Research and Development Corporation (RIRDC). Later, the egg industry formed an independent funding body within the Australian Egg Corporation, now Australian Eggs Limited. The chicken meat industry has remained with RIRDC and its successor, AgriFutures Australia.)

The McClymont–Cumming venture at Tamworth probably also helped set the scene for the development of RA in the 1970s; however, other events about that time also contributed. In August 1973, the first of six occasional symposia in the series ‘Reviews in Rural Science’ (on bloat in cattle),

conceived in the Department of Biochemistry and Nutrition at UNE, was held successfully in Armidale; the Proceedings, edited by Ron Leng and the then Professor of Agronomy at UNE, Jim McWilliam (Leng and McWilliam 1974), exemplified Bill McClymont’s cross-disciplinary eco-system ethos in the, by now, ‘Faculty’ of Rural Science, and his intention to engage with agricultural practitioners. The success of the first Reviews symposium was repeated with a second cross-disciplinary symposium held at UNE in August 1975, subtitled ‘Plant to animal protein’ (Sutherland *et al.* 1976). It was funded by the Australian Meat Committee and six commercial feedstock sponsors. The list of presenters is a who’s who of Australian and overseas scientists from that period. The editors were Dr Tom Sutherland, Professors Jim McWilliam and Ron Leng and the Proceedings were published by the UNE Publishing Unit. Tom Sutherland acknowledged the stimulation and forbearance of fellow members of the ruminant metabolism group at UNE during the preparation of his paper for the symposium, but added a notable rider that ‘they are, however, guiltless of its perhaps excessive speculative content’. This mention of speculative content aptly described the prevailing research mood at UNE at the time, namely, speculate, hypothesise and test the hypotheses. This speculation-led approach to research was embodied in the guidelines to authors attending the early RA meetings; invited speakers were asked to push the current knowledge boundaries. Four more symposia in the Reviews series were held subsequently (Blair 1977; Wodzicka-Tomaszewska *et al.* 1980; McGarity *et al.* 1984; Leng *et al.* 1985).

Events outside UNE at this time probably helped lay the groundwork for the formation of RA. In 1967, Dr Charles Payne arrived from Nottingham to be the Research Director of the Poultry Husbandry Research Foundation (PHRF) at the University of Sydney, Camden. ‘Charlie’ Payne had a track record at Nottingham for tackling problems affecting the poultry industry. Perhaps significantly, the first meeting of Nottingham University’s ‘Recent Advances in Animal Nutrition’ had been held the year before Payne’s departure. In Sydney, Charles Payne made it his mission to engage with and serve the local poultry industry. This was exemplified by his publication, in the early 1970s, describing the role of biotin in the fatty liver and kidney syndrome in broilers (Payne *et al.* 1974) that had worldwide benefits for the poultry industry. He was a principal organiser for the first PHRF symposium organised in 1968. (When the PHRF joined with the Australian branch of the World Poultry Science Association to stage this symposium in 1989, it became the Australia Poultry Science symposium, which still holds its annual meeting each year.) A little later, Rob Cumming and David Farrell, now a post-doctoral fellow, met in Sydney with Charles Payne, possibly to float the idea of introducing poultry, pig and ruminant nutrition schools at UNE and to gain his support for the inclusion of poultry nutrition at these meetings.

After returning from Sydney, Rob Cumming and David Farrell continued to pursue the idea of holding nutrition schools, similar to the Reviews meetings, encompassing monogastric as well as ruminant livestock, and serving both Australian livestock scientists and industry practitioners. In a

recent letter to me, David Farrell recalled the period leading up to the first RA meeting at UNE, as follows:

Rob Cumming and I returned to Armidale full of enthusiasm. Informal discussions with departmental members followed to determine how we could best showcase the range of species and research topics within the department. Until then, the main interest had been in rumen physiology and biochemistry, but it was decided to develop ‘schools’ covering, in addition, not only sheep but poultry and pigs, wild animals, humans, and feedstuffs.

The academic environment in the 1970s

It is worth recalling that, when the first RA schools were being organised, the academic environment at UNE, and indeed at all Australian universities, was very different from that on campuses today. A much smaller fraction of the population attended universities and adult education was one of their important functions. The notion of RA as being a school rather than a symposium accorded with the then-current belief that UNE had a responsibility to be an extension organisation, freely sharing its knowledge with the local community. It was a period when scientists and academics also had time to philosophise about disciplinary matters, and freedom (and resources) to pursue their own research agendas. University finances were less rigorously assigned for specific purposes. Furthermore, in the 1970s, the ratio of support staff to senior academics was much higher than is the case now. Laboratories were maintained by laboratory managers and serviced by technicians with TAFE certifications; there was more division of labour in that administrative tasks, typing and day-to-day activities were performed by qualified secretarial staff; they used older-style typewriters; tasks such as writing of purchase contracts, placing orders, managing equipment backlogs and scheduling deliveries were all performed on paper. Payments were made by cheques, only much later to be superseded by the introduction of the credit card. Dedicated workshops, crewed by suitably qualified staff, provided services for research such as electrical and electronic expertise, metal working and glass blowing, and these staff often designed and built specialised equipment to meet particular research needs. Scientific research was subject to less ‘red tape’; experiments with animals dreamed up on Monday could be in progress by Friday of the same week!

The flexible working arrangements made it possible to organise and host events such as RA, especially if it could be argued that there were spin-off benefits to the university. But there were constraints in the 1970s too; for example, there were no photocopiers; so, proceedings of meetings were laboriously typed onto waxed paper stencils and reproduced using Gestetner machines (that forced ink through the stencils onto paper in contact with the stencil; if mistakes were made in typing onto the stencils, they were difficult to correct). There were no word processors or digital storage devices of the type we all use today. Storage of information was in the form of printed material stacked on book shelves or held in copious filing cabinets. Another 10–20 years would elapse before

personal computers and digital storage devices were in common use.

The first RA school was planned and undertaken in this environment. However, we have not been able to determine, definitively, when the first school was held. At early meetings, papers were incorporated separately into a folder that was distributed to delegates at the meeting. None of these folders is known to still exist, but a copy of a paper presented at the 1974 meeting by Wayne Bryden when he was a postgraduate student with Rob Cumming, entitled ‘Aflatoxin and animal production with particular reference to poultry’ has been found (pers. comm.). This 1974 paper, considered in conjunction with David Farrell’s preface to the proceedings of the third school held in 1977, leads us to conclude that there was probably a second school in 1975 or 1976. A less likely possibility is that the first meeting took place before 1974.

Format of early meetings

At the outset, it was decided that RA schools would be held in May or August when residential college students at UNE were on vacation and attendees could be accommodated in Austin College at a low cost. Arrangements were made with Dr Alan McKenzie, Master of Austin College, to provide inexpensive accommodation that included breakfast and evening meals and car parking for 3 days. (Intriguingly, Alan had a PhD in chemistry from Oxford but had decided that managing a residential college was more appealing than teaching and research.) His dedication to RA over the years was an important factor in its success.

Attendees, some with partners, arrived on the Sunday afternoon before each meeting and the College Tutors on duty showed them to their rooms. There was a low-key meet-and-greet reception with drinks and snacks on Sunday evening. From 1977, presentations took place in Lecture theatre 1 in the Rural Science building, the home of the Department of Biochemistry and Nutrition (Fig. 2).

The lecture theatre was well equipped for conferences and was reached after a brisk walk of 10–15 min up the hill from Austin College. The conference dinner/banquet on Tuesday evening was always one of the highlights at each meeting. Dr



Fig. 2. Group of attendees in Rural Science lecture theatre.

McKenzie and his staff took great pride in producing a gourmet meal with special trimmings; notably, wine bottles were often explicitly labelled for the occasion. At many of the dinners, Dr McKenzie and the staff received a resounding ovation for their efforts to make the occasion memorable. The banquet was also a venue for networking, and, later in the evening, a stage for raconteurs and joke tellers, some of whom approached legendary status after their on-stage contributions at many such events. However, despite the late-night frivolity, most attendees still managed to make the first paper at 0830 hours on Wednesday morning. The meetings concluded after lunch on Wednesday, allowing time for delegates to travel home and meet their work commitments the following day.

David Farrell was the principal organiser of nine of the first 10 RA meetings and the editor of the Proceedings. With a small group of helpers from the Department of Biochemistry and Nutrition at UNE, he compiled the scientific program, chose and invited overseas speakers, organised accommodation for participants, and sought sponsorships to help make the meetings affordable (Fig. 3).

The RA meetings were held at approximately 2-year intervals. The range and quality of the papers presented established RA as a major venue for the delivery of the latest nutritional theory and practice across a range of livestock and aquatic species. At the early meetings, the program was composed solely of invited papers.

The format of early RA meetings proved to be a successful one. Prominent speakers from overseas were a major drawcard for attendees and their contributions were augmented with the latest nutritional research findings of staff and higher-degree students of UNE, along with researchers from other Australian universities, the CSIRO and state agriculture departments. The main livestock of interest were ruminants (cattle, sheep and goats) and monogastric species (poultry and pigs). However, the nutrition of horses, cats and dogs, emus, ostriches, ducks and game birds, fish, prawns and yabbies, and human beings were also covered from time to time. The organisers' aim was always to have speakers with wide nutritional expertise covering a range of livestock and companion animals, and also human nutrition.



Fig. 3. Some of the group who organised meetings in the 1970s and 1980s. L to R: David Farrell, Ray Johnson, Amanda Choice, Evan Thomson.

Many novel topics relating to the nutrition of a variety of animals were aired at ensuing meetings, creating lively discussions and stimulating ongoing research. It is not possible to cover all such topics but various papers, especially those delivered by invited speakers from overseas, have been mentioned below to illustrate the variety of themes and animal species covered. Local speakers, in many cases, were equally innovative and just as challenging and up-to-date as were their overseas counterparts.

The structure of the meetings organised by David Farrell and his small band of helpers changed little over the years. It was considered imperative to have the Proceedings available for attendees at the start of each meeting. The program and the Proceedings were distributed on Monday before the first paper at 0830 hours.

Chairpersons were carefully selected for their ability to lead a robust discussion. The first paper was normally delivered by a guest speaker from overseas. Echoing the ethos of the Rural Science Reviews conferences that were designed to push the scientific boundaries, speakers at RA were also encouraged to think creatively about problems and advance new theories to explain unanswered questions. Recognising that contributors to these meetings had been encouraged to present preliminary data and to speculate about solutions to problems they were addressing, David Farrell's preface in the 1977 RA Proceedings stated that: 'Any reference to papers in this book should be cited in the form of a 'personal communication' since much of the data is preliminary'. This informal approach to refereeing was readily accepted in the earlier stages of RA. The organisers did their best to format papers and make editorial corrections, often confronted by an approaching deadline with the UNE printery during the week before the symposium. The papers were bound into a book that was handed to attendees at the start of each meeting.

Because the papers prepared for meetings before 1997 were not formally 'published', where I refer below to the papers delivered at these earlier meetings, no formal citations are included.

The major cost of running early RA meetings was the funding of airfares for overseas visitors and their college accommodation at UNE. In a recent letter to me, David Farrell recalled the following: 'in the 1970s, UNE was more like a large family than a corporate organisation constrained by tight budgets. Morning tea and coffee equipment were delivered to the McClymont Building at little or no cost, and the support staff in the Department of Biochemistry and Nutrition ensured that the coffee breaks ran smoothly. Quite soon, there were sufficient surplus funds to enable two overseas speakers to be invited'.

There was never any need to advertise the early RA schools extensively as there was virtually no competition from similar symposia at that time. Anyone involved in the animal industries was welcome to attend. Details of future meetings were promulgated largely by word of mouth or via animal science societies. Industry was always very supportive and sponsorships helped cover the costs of bringing guest speakers from overseas. The additional benefits for UNE of involving industry representatives were that its staff and post-graduate students were challenged by,

and could extend their research to answer, questions pertinent to current industry issues; as well, students benefitted from networking and, in some instances, being offered employment before they completed their post-graduate degrees.

Later, during the 1990s and afterward, the research environment started to change and new funding models and research priorities were emerging. After the 1993 meeting, the nature of the RA organisation changed abruptly in response to the departure of David Farrell, Ron Leng and others from UNE, and widespread changes to tertiary institutions. The second phase of RA meetings (13 meetings; 1995 to the present) was organised from within a newly formed Department of Animal Science at UNE. The two phases of RA will be covered in more detail below.

Phase 1: consolidation of RA, 1973–1993

Meetings 1 and 2

All the known meetings held, and members of the organising committees, are listed in Table 1.

David Farrell described the 1977 meeting as the third meeting, so there were at least two meetings before 1977, one being in 1974 as discussed earlier. Only a small number of people came to the early meetings and Tony Edwards, one of the early RA attendees, recently told me that presentations were given across the campus wherever an empty lecture room could be found.

In 1974, Frank Annison, Ron Leng's PhD supervisor, who had left UNE and returned to England ~10 years earlier to lead a research team at the Unilever Research Laboratory, Colworth House, Sharnbrook, had returned to Australia to take up the position of Chair of Dairying, later Animal Husbandry and finally Animal Science at the University of Sydney. Frank, and Ron at UNE, were presumably both advocates for ruminant contributions at the early RA meetings, whereas David Farrell and Rob Cumming played similar roles in the monogastric animal sessions.

1977 meeting

Seventeen plenary papers were presented at the 1977 school and, for the first time, the papers were circulated to attendees in a printed Proceedings^a.

These Proceedings included two invited papers by Professor Simon Bornstein, a poultry scientist, who founded the Volcani Center in Bet-Dagon, Israel. However, the first paper in the first RA Proceedings was by Bill McClymont who had done so much to create the right environment for the success of RA. His visionary lecture, 'Future grain supplies for the intensive animal industry', covered many more philosophical issues than its title might suggest; it was an extended version of Bill's invited theme address to a conference of the South African Society of Animal Production entitled 'Animal production in a grain hungry world – or competition between man in a resources limited

world' (McClymont 1976). Bill outlined some timeless propositions in considerable detail, including the following:

- Animal products are not essential in human diets
- Energy is the first limiting factor in most human diets so that there is no special case for increasing the production of animal products because of their high protein content
- Animal production is energetically inefficient and wasteful
- As great numbers of people are affected by energy deficiency, it is immoral or unethical to feed grain to animals.

It may be salutary for present-day readers if I 'cherry-pick' one of Bill McClymont's footnotes from this paper written half a century ago:

Ancillary energy production cannot however be expanded indefinitely ... This could cause major perturbation of climate and lead eventually to melting of the ice caps and inundation of vast areas of the earth. These risks are reduced by solar energy harvesting as 70–90% of the solar energy which falls on most of the earth's surface is absorbed and eventually appears as heat in any case. Using solar energy from hydroelectricity or wind or wave sources or by photosynthesis does not add to the heat dissipation load of the ecosphere. Bill concluded: increasingly society must take an holistic view of agricultural production systems, taking into account the total needs of man – nutritional, economic and quality of life- and resource conservation, including fuel, soil, minerals and water resources.

Dr Jim Gooden (DSIR, Palmerston North, New Zealand) reviewed the role of lipids in diets for ruminants. Other papers at this school were delivered by scientists from UNE, CSIRO and state departments of agriculture. Frank Annison and Graham McDowall from the University of Sydney discussed strategies for minimising the low-fat syndrome in dairy cows; Drs Ted Batterham (NSW Agriculture, Wollongbar, NSW, Australia), and Roger Campbell and Mike Taverner (Victorian Department of Agriculture, Melbourne, Vic., Australia) gave separate papers advising participants about amino acid requirements of pigs; Drs Tim Kempton and Ron Leng reviewed knowledge on the requirements for nitrogen in ruminant diets, including discussion of a new concept, 'bypass protein', and Cliff Graham (ICI Australia Ltd) explained the advantages of using molasses blocks as a nutrient delivery mechanism; Dr Ian Hume (UNE) discussed the dietary requirements of wild animals; Dr Barry Norton, University of Queensland, identified where trace element deficiencies existed in the livestock industries and discussed some recent studies of cobalt deficiency in Queensland.

Another of the outstanding papers at the 1977 meeting, which exemplified the early focus on the extension of the most recent research findings, supplemented by speculative hypotheses and conclusions, was a much-quoted review entitled 'Control and manipulation of rumen fermentation' by Dr Tom Sutherland. Tom was an outstanding biochemist

^aPapers presented at RA meetings between 1977 and 2005 were recorded on CD-ROMs (given out at RA meetings) and some papers can be accessed in the CSIRO Livestock Library at <http://www.livestocklibrary.com.au/handle/1234/5262>. I have recommended that all papers presented at RA meetings from 1977 to 2011 be placed online at <https://www.raan.com.au/>.

Table 1. Details of dates and venues of RA meetings and members of the organising committees

RS1, Rural Science building, UNE (Lecture room 1); Austin, Austin College, UNE; Duval, Duval College, UNE; Education, Main auditorium, Education building UNE; Belshaw, Law Faculty, Belshaw lecture theatre, UNE

	Meeting date (Day 1)	Presentation venue	Plenary papers, short papers	Organising Committee (Chair first, then in the order as listed in Proceedings)
<i>Phase 1</i>				
1974 and 19??	??	??	??	Probably David Farrell, Rob Cumming (see text)
1977	1 May	RS1	17, –	David Farrell, Jean Hansford
1978	20 Aug.	RS1	16, –	David Farrell, Jean Hansford
1980	4 May	RS1	17, –	David Farrell, Jean Hansford, Kathy Santleben
1981	31 Aug.	RS1	24, 21	David Farrell, Frank Annison, Jean Hansford, Barbara Harrison
1983	28 Aug.	RS1	35, 24	David Farrell, Pran Vohra, Jean Hansford, Barbara Harrison
1985 ^A	24 Nov.	RS1	24, 22	Rob Cumming, Ian Hume, John Nolan, Jean Hansford, Barbara Harrison
1987	10 May.	RS1	38, 18	Rob Cumming, Ian Hume, John Nolan, Jean Hansford, Barbara Harrison
1989	16 Apr.	RS1	36, 34	David Farrell, Mrs. R. Curry, Roslyn Busby, Jean Hansford, Ruth Fox
1991	7 Apr.	RS1	23, 31	David Farrell, Mrs. R. Curry, Wendy Ball, Jean Hansford, Ruth Fox, Linda McGarry
1993	18 Apr.	RS1	32, 25	David Farrell, Ruth Fox, Janet Jobson
<i>Phase 2</i>				
1995	3 July	Wright Theatre	24, 25	James Rowe, John Nolan, Wendy Ball, Illona Schmidt, Therese Cooper, Winston Hewitt, Neil Baillie, Frank Ball, Ian Kerr, Mary-Anne Glynn, Greg Jones
1997	Apr.	Wright Theatre	23, 40	John Corbett, Mingan Choct, James Rowe, John Nolan
1999	30 June	Wright Theatre	23, 30	Mingan Choct, John Corbett, John Nolan, James Rowe, Hutton Oddy, Ilona Schmidt, Frank Ball, Wendy Ball, Winston Hewitt
2001	?	Wright Theatre	21, 40	Mingan Choct, Frank Ball, Roger Hegarty, John Nolan, James Rowe, Ilona Schmidt
2003	?	Wright Theatre	21, 27	Mingan Choct, John Nolan, James Rowe, Illona Schmidt
2005	?	Wright Theatre	20, 32	Mingan Choct, Barbara Gorham, John Nolan, James Rowe, Darryl Savage, Ilona Schmidt, Rob van Barneveld
2007	?	Wright Theatre	19, 44	Darryl Savage, Mingan Choct, Paul Iji, Lena Mikkelsen, John Nolan, Nerida Richards, James Rowe, Ilona Schmidt, Rob van Barneveld
2009	?	Duval College	19, 28	Darryl Savage, Mingan Choct, Paul Iji, John Nolan, Nerida Richards, James Rowe, Rob van Barneveld (Eds Pierre Cronjé, Nerida Richards)
2011	?	Education Theatre	10, 15	Pierre Cronjé, Mingan Choct, Roger Hegarty, Paul Iji, Nerida Richards, Bob Swick, Rob van Barneveld
2013	?	Education Theatre	15, 32	Bob Swick, Pierre Cronjé, Roger Hegarty, Wayne Bryden, Frank Dunshea, Paul Iji, Elle Perry, Nerida Richards, Rob van Barneveld (Eds Pierre Cronjé, Elle Perry)
2015	26 Oct.	Education Theatre	19, 29	Bob Swick, Roger Hegarty, Wayne Bryden, Rob van Barneveld, Frank Dunshea, Nerida Richards
2017	25 Oct.	Belshaw Theatre	15, 31	Bob Swick, Pierre Cronjé, Roger Hegarty, Wayne Bryden, Frank Dunshea, Nerida Richards, Rob van Barneveld, Ian Sawyer, Fran Cowley, Mingan Choct, Helene Dawson (Ed. Pierre Cronjé)
2019	23 Oct.	Belshaw Theatre	15, 19	Bob Swick, Fran Cowley, Wayne Bryden, Frank Dunshea, Roger Hegarty, Amy Moss, Mingan Choct, Ian Sawyer, Rob van Barneveld (Eds Frank Dunshea, Dayle Dunshea)
2021	9 June	Voco Hotel, Gold Coast	26, 13	Fran Cowley, Roger Hegarty, Wayne Bryden, Amy Moss, Frank Dunshea, Rob van Barneveld, Ian Sawyer, Bob Swick, Dayle Dunshea (Eds Frank Dunshea, Dayle Dunshea)

^AThis 1985 Proceedings was dedicated to Professor Bill McClymont.

who had come to UNE from the Rowett Research Institute via Cuba where he had assisted Dr T. R. (Reg) Preston to establish a ruminant research program for the then Prime Minister, Fidel Castro. His paper, written when the concept of modifying rumen microbial populations as a means of improving animal performance was in its early stages, drew on sound biochemical principles to explain the different molar ratios of acetate to propionate concentration found in rumen fluid of ruminants given different diets. His paper was an exemplar of how early contributors to RA were willing to apply current scientific knowledge from different

disciplines to advance knowledge of livestock nutrition. Modification of rumen microbial populations was a fairly new idea, but it would soon gain wider practical recognition through the use of chemicals such as monensin; rumen modification became a theme often re-visited in subsequent papers in RA.

Tom Sutherland also took a keen interest in human nutrition research and, with David Farrell, developed one of the earliest undergraduate courses in human nutrition in Australia. Tom's links with Reg Preston and their initial investigations on the use of molasses-based diets for cattle in Cuba, when relayed to

Ron Leng, provided a catalyst for a life-long research association and friendship between Reg and Ron. The duo was brought together at a seminar in Vienna in 1971 by Dr Hugo Höller who had recognised their scientific compatibility; 16 years later they co-authored a much-quoted book that provided advice on feeding ruminants using locally available feed sources in the tropics and sub-tropics (Preston and Leng 1987) and the paper titled 'Principles for the use of non-protein nitrogen and bypass proteins in diets for ruminants' by Ron Leng and Tim Kempton at the 1977 meeting, and numerous papers at subsequent RA meetings are also attributable to this partnership.

At the same meeting, David Farrell presented an innovative paper describing 'A new, rapid method for determining the metabolisable energy of poultry feedstuffs'. In keeping with the cross-species mantra of RA, David also presented a prescient paper on the importance of fibre in human diets. He had been reading, with growing interest, papers by a fellow Irishman, Dr Denis Burkitt, who was one of the first scientists to create an awareness of the importance of fibre (or lack of fibre) in western diets (Burkitt 1969). This paper foreshadowed David's lifelong interest in human nutrition and also a book, published 40 years later, about 'contemporary issues in eating and living' (Farrell 2009).

Seven papers dealt with ruminants and eight with pigs and poultry; one was about humans and one about wild animals. Furthermore, one of the papers, 'A behavioural study of laying hens with polypeepers or specs' dealt with behaviour and welfare issues. By 1977, a paradigm that included guidelines and themes for future RA meetings had been established.

1978 meeting

At the meeting in 1978, Dr Hector Karunajeewa (Victorian Department of Agriculture, Melbourne, Vic., Australia) captured the attention of poultry feed suppliers by arguing that a choice feeding system, enabling birds to choose unground grain and a protein concentrate from separate containers, could offer potential economic benefits to the industry. He argued that there would be fuel energy savings resulting from (a) the feeding of uncracked grains, rather than mash or pelleted feeds, and (b) reductions in total feed intake for similar levels of production. This was the first of many papers presented at later RA meetings on choice feeding of animals, including by Rob Cumming and colleagues who foresaw potential economic and welfare benefits with the choice feeding system for both poultry and pigs. The idea would later be adopted by ruminant nutritionists.

At this meeting, Ron Leng reviewed and evaluated existing publications describing responses in growth rates of cattle on sugarcane- or molasses-based diets when they were given protein-rich supplements such as rice polishings or fish meal (Preston and Willis 1970). Ron advanced a hypothesis that explained the production benefits for ruminants given low-digestibility feed sources of supplements containing bypass or escape protein. He argued the improved production was due to the exit of undegraded dietary amino acids that escaped from the rumen and augmented the outflow of microbial amino acids, thereby increasing the potential for absorption of amino

acids from both sources in the small intestine. An extra supply of absorbed glucogenic amino acids then augmented the potential for endogenous glucose production as well as cell protein deposition and, in consequence, stimulated feed intake.

Some Ron Leng's former PhD students (Bird, Judson, Kempton, Nolan and Steel) presented papers on ruminant nutrition at this meeting. Dr Simon Bird presented results of his studies showing that when protozoa were eliminated from the rumen of lambs ingesting low-protein, high-energy diets, outflow of amino acids from the rumen was increased, and feed conversion efficiency, wool growth and live-weight gain were improved; Bird's suggestion that protozoa-free ruminants had higher protein outflows from the rumen fitted nicely with the theory that responses in ruminants to bypass protein supplements were due to the extra amino acids entering the small intestine. Dr John Steel's paper on the protein and energy costs of internal parasite infections of ruminants also anticipated later suggestions that the pathological effects of these infections might also be ameliorated by supplementation with escape protein sources.

A paper by Tom Sutherland (with David Farrell) on cholesterol metabolism and its implications based on their work with human volunteers extended some of the issues around the role of dietary fibre in human diets that had been highlighted by David Farrell and Tom Sutherland at the 1977 RA meeting.

1980 meeting

At the 1980 meeting, Drs Roy Kellaway and Jane Leibholz, from the University of Sydney, challenged the bypass protein hypothesis presented by Ron Leng at the previous meeting. This laid the groundwork for some robust (but beneficial) discussions at later RA meetings. The Sydney group argued, from an analysis of their own studies (six relevant experiments), that forage intake and growth responses of sheep on a basal diet of paspalum hay, when supplemented with an escape-protein supplement (meat-meal) were not significantly greater than they were for sheep supplemented with urea. They contended that supplements of either urea or meat meal were equally effective in stimulating forage intake, provided that the intake of urea was not too infrequent. (They issued this proviso because they felt that bypass-protein supplements might be acting as slow-release sources of ammonia in the rumen that enhanced microbial protein growth and outflow rates, rather than by enhancing undegraded dietary protein outflow rates.) Their hypothesis was a challenge to scientists in Ron Leng's corner who firmly believed there was a specific role for undegraded dietary protein (i.e. bypass protein) to provide extra amino acids with ruminants ingesting low digestibility forages, a role that could not be met by supplementary urea alone. In retrospect, it seems that these exchanges provided a stimulus for much useful research that led to a consensus that supplements providing additional dietary amino acids to the small intestine provides benefits that cannot be achieved by urea alone. In a second paper, Roy Kellaway revived the idea of treating cereal straws with alkaline solutions (e.g. NaOH and NH_3) to improve their digestibility.

A paper presented by John Nolan and John Corbett at the 1980 RA meeting outlined some of the formative ideas being considered for inclusion in the protein section of 'Feeding standards for Australian livestock: ruminants', published later in Corbett *et al.* (1990). An Expert Panel on Australian Feedstuffs had been established in 1974 by the Animal Production Committee of the Commonwealth Standing Committee on Agriculture and its members had recommended that standards for livestock feeding in Australia should be based on a metabolisable-energy system similar to that in use in Britain. In response, the Standing Committee on Agriculture had agreed to the establishment of a Working Party for Introduction of Nationally Uniform Feeding Standards for Livestock (Pryor 1980). The existence of this Working Party provided the context for various papers presented at this and subsequent RA meetings. One of the five subcommittees of the Working Party, convened by Dr John Corbett, had been charged with implementing feeding standards for ruminants, including for protein. The endeavours of the corresponding subcommittees for pigs and poultry were also the subject of papers at later RA meetings mentioned below.

1981 meeting

David Farrell's introductory statement for the 1981 meeting noted: 'Because of identical titles, we have been requested by the organisers of a similar conference in Britain to change the title of the Proceedings. We have therefore added to the title, 'in Australia''.

One of the invited speakers was Dr Ian Stibbard (Animal Research Centre, Agriculture Canada) who had developed and tested various ways of assessing the metabolisable-energy (ME) value of feeds for poultry. In a landmark paper (Sibbald 1976), he had described a bioassay for determining the true ME (TME) in poultry feeds. At this meeting, he outlined his TME bioassay, compared the merits and assumptions underlying assays for apparent ME (AME) and TME and emphasised the importance of applying a nitrogen correction to AME and TME results.

A whole session at this meeting was devoted to the protein and nitrogen requirements of ruminants. Professor David Armstrong (University of Newcastle-upon-Tyne) summarised the recently published UK's Agricultural Research Council proposals for assessing protein requirements of ruminants (ARC 1980). His paper was one of a series of themed papers linked to the ongoing efforts of the Ruminant Subcommittee of the Australian Working Party that was charged with developing feeding standards for Australian livestock. Session 2 was devoted to the bypass/escape-protein theme that had been the subject of controversy at previous RA meetings, as well as challenging ruminant nutritionists around the globe for some years. Frank Annison, who chaired this session, concluded his opening remarks with the following comment: 'Much of animal production in Australia, however, is based on the grazing animal, where the overwhelming requirement is to increase the intake and efficiency of utilisation of low-quality herbage. By-pass protein supplements have proved effective in some situations, but

not in others, and the objectives of this session are to review the current position and establish the ground rules for future work.'. A lively session followed.

However, not all delegates were satisfied with the approach of the ARC (1980) or similar schemes in other countries for determining feeding allowances for ruminant livestock. Drs John Black and Graham Faichney (CSIRO, Blacktown, New South Wales, Australia) argued 'that the primary purpose of the European systems was to formulate rations to achieve specified rates of production in hand-fed stock' but claimed that these systems 'are generally unsuitable for the extensive conditions of ruminant production in Australia'. They put forward an alternative modelling framework that differed appreciably from the ARC system. They developed a whole-animal model that they argued provided a practical and more flexible system of protein evaluation than the ARCs, in that it could simultaneously take account of dietary, animal and environmental factors affecting both rumen function and nutrient utilisation within animal tissues. However, the ability of their model to predict rates of degradation of dietary carbohydrate components in the rumen was hampered by insufficient information on the composition of feeds and, although they hoped to shortly be able to remedy this problem, unfortunately funding to provide this essential information was never forthcoming and the program lapsed. Further refinement of this and similar models capable of determining protein requirements for Australian ruminants has occurred only intermittently in the intervening period and has only recently been revived (Dougherty *et al.* 2017). However, a similar dynamic modelling approach taken by John Black and co-workers soon led to the development of a model for pigs that was unveiled at the following RA meeting and later became a central component of 'Feeding standards for Australian livestock – pigs' (Annison 1987).

Four other animal species new to RA were discussed at this meeting. Professor Peter Cheeke from Oregon State University highlighted a potential role for the domestic rabbit as an efficient meat-producing animal that was capable of growing rapidly on forage-based diets. John Throckmorton, who was undertaking a PhD at UNE with Ron Leng, reviewed recent research on goat nutrition and production and identified some potential advantages of goats over other ruminant livestock in Australian conditions. However, he warned about their possible deleterious effects on the Australian environment. Dr Ian Hume broadened the scope of this meeting by explaining the problems of feeding Australian monotremes and marsupials in captivity, especially when their natural diets are replaced with more readily available, commercially produced, compounded diets. Another important theme, the effects of high temperatures on nutritional requirements and production of livestock, was further developed in a paper titled 'Overcoming the effects of high temperature on pig growth' presented by Chanvit Vajrabukka, a PhD student from Thailand supervised by John Thwaites and David Farrell at UNE, who returned to Thailand and began a distinguished research career at Kasetsart University in Bangkok.

This meeting was the last at which Bill McClymont delivered a paper. He had retired from UNE in 1980 and been appointed Emeritus Professor. His paper made predictions about the effects of increases in costs of fossil fuels on the relative economics of grain-intensive ruminant versus pig and poultry production. Bill continued working for some years after his retirement as an agricultural consultant for the World Bank and the Food and Agriculture Organisation. After he died in May 2000, the Rural Science building, that had been the venue for RA meetings since 1977, was renamed 'The McClymont Building'.

1983 meeting

The 1983 meeting was organised by David Farrell with the help of Professor Pran Vohra who was visiting UNE from the University of California, Davis, USA.

For the first time, one-page communications were invited to encourage young scientists to come to the meeting, present their current research and network with industry participants. The 24 contributors were given a short time to speak on the Wednesday afternoon of the symposium and their papers were included in the Proceedings. Although this posed an additional burden on the organisers, it was a successful innovation and was probably part of the reason why the numbers of attendees increased substantially at subsequent meetings.

This meeting featured a session on dairy production, with reviews delivered by four overseas speakers, Professor van Es (Institute for Livestock Feeding and Nutrition Research, Lelystad, The Netherlands), Dr John MacRae, (Rowett Research Institute, Scotland), Dr Geoff Alderman, (Agricultural Development and Advisory Service, London) and Dr Arnold Bryant (Ruakura Animal Research Station, New Zealand). In the dairy session, the feeding standards theme was extended from previous meetings. Dr Geoff Alderman, a member of the committee responsible for developing the ARC feeding standards in the UK, emphasised the difficulties in predicting the total feed intake of the grazing dairy cow, especially when herbage allowance, milk yield, stage of lactation, liveweight and offering escape protein supplements can all be factors that affect the prediction. Dr John Corbett described his subcommittee's progress with the development of new feeding standards for ruminants in Australia. The scheme adopted by Corbett's committee took account of schemes in other countries designed for housed ruminants but, in addition, incorporated the GrazFeed model developed by Freer and Christian (1983). This unique procedure allowed for quantitative nutritional management to encompass grazing animals and was incorporated into the final recommendations in 'Feeding standards for Australian livestock. Ruminants' (Corbett *et al.* 1990). In keeping with the challenging environment of early RA meetings, however, Dr Norman Graham (CSIRO, Sydney, NSW, Australia) took Corbett's committee to task with his paper entitled 'Feeding standards – an outmoded concept in ruminant feeding'. He argued that effort should be diverted from 'patching up' older and fundamentally unsatisfactory systems towards the development of new ones. He compiled a table that listed

ruminant simulation models that offered some novel alternatives to conventional feeding standards. His arguments reinforced the potential for newer modelling approaches such as those presented at the previous RA meeting by John Black and Graham Faichney.

Dr Roger Campbell's (Victorian Department of Agriculture, Melbourne, Vic., Australia) review posed a new question: was there good evidence that over-feeding or undernourishment of pigs in the early postnatal period can affect their tissue cellularity and subsequent growth and development? Roger concluded that, at that time, the current evidence was limited and contradictory; however, this theme was revisited by various speakers covering pigs and other animal species at later meetings.

Several new themes were introduced at this meeting. An important paper by Dr James Rowe and co-authors (UNE) evaluated the possibility that ruminant animal production might be increased by modification of rumen fermentation (by defaunation and use of chemical modifiers). Professor Richard Austic (Cornell University, USA) highlighted the detrimental effects of an imbalance of monovalent electrolytes in the diet of layers on growth rate and bone calcification in poultry and pigs.

Another theme, feeding behaviour, which encompasses choice feeding and the question of whether livestock exhibit nutritional wisdom, was also still developing. Rob Cumming presented a research report that indicated that choice feeding could be a practical feeding strategy, a subject that he would go on to champion in future meetings, to the disquiet of some of the participants whose businesses depended on the preparation of mash or pelleted diets. His paper, 'Choice feeding of broiler chickens at high temperatures', was a performance evaluation of choice-fed broiler cockerels from 4 to 8 weeks of age when housed at environmental temperatures of 20°C or 30°C. At both temperatures, the cockerels offered a free-choice diet grew as well as those given a conventional pelleted diet, and significantly better than those given a mash diet. Moreover, the choice-fed birds also converted feed to liveweight more efficiently than did those offered the mash or pelleted diets.

Dr Reg Preston delivered a paper on the value of sugarcane as a source of cane juice that could be used to replace grain as a major energy source for feeding livestock. The potential for sugarcane to be a potential source of energy for ruminants and sucrose for monogastric animals was noted and led to further investigations that were reported by several workers at the 1987 meeting.

1985 meeting

The eighth RA meeting was held in 1985. During the planning for this meeting, David Farrell had been on assignment in Indonesia. Another of the instigators of, and major contributors to RA, Dr R. B. (Rob) Cumming, took on the role of organiser and editor.

This meeting and the Proceedings were dedicated to Bill McClymont to recognise his contributions to the science of animal nutrition. The program covered most of the areas in which Bill had contributed research expertise. The speakers were invited based on their eminence in their field of study and

many were Bill's former students or close associates. On the first morning, Frank Annison presented a tribute to Bill McClymont and then chaired a session devoted to aspects of supplementary feeding of sheep, beef cattle and dairy cattle. Topics covered included the reduction in forage intake when grain supplements are offered (Dr Rob Dixon, University of Melbourne, Vic., Australia), the production and economic benefits of protein-rich supplements for grazing cattle in the tropics and subtropics (Dr David Hennessy, Agricultural Research Station, Grafton, NSW, Australia) and the reasons why animals may accept or reject supplementary feeds (Dr Justin Lynch, CSIRO, Chiswick, NSW, Australia). Drs Rod Stephenson and Peter Hopkins (Queensland Department of Primary Industries, Brisbane, Qld, Australia) described a novel method for overcoming supplement palatability issues that involved dispensing urea and medications via the water trough so that avoidance of these less-palatable supplements was counteracted by the animals' need to drink water regularly.

An early version of a deterministic computer model of the pig was unveiled by John Black (coauthor, Kerry James). Members of the Pig Research and Development Corporation had foreseen the potential value of a simulation model capable of predicting the nutrient requirements of the pig and had commissioned its development. This pig model was reminiscent of the ruminant model presented at the 1981 RA meeting by John Black, but now there was a submodel to account for nutrient absorption (Black *et al.* 1987) (and no rumen component needing hard-to-access inputs!) The new pig model was able to simulate energy and amino acid requirements and utilisation as animals developed from birth to maturity and showed how the requirements were altered by strain, sex, feed intake and reproductive state; the effects of different feeding strategies on productivity (and profitability) could also be determined. The model was published in more detail the following year (Black *et al.* 1986) and was used to establish new tables of feeding standards for pigs in Australia (Annison 1987). Since then, as AUSPIG, the model has been refined to include temperature and disease modules and further developed into as a comprehensive management system; AUSPIG has been commercialised and employed by pig producers worldwide (see Black 2014).

In another session on monogastric animals, there was again a strong emphasis on feeding behaviour in chickens and how they learn to choose nutritious, non-toxic ingredients, a topic that had been fascinating Rob Cumming for some time. Several research reports showed how chickens altered their nutrient selection in response to changes in ambient temperature; Dr Lesley Rogers (UNE) highlighted the importance of brain asymmetry to learning and feeding behaviour in chickens.

Professor Graham McDowall (University of Sydney, Sydney, NSW, Australia) presented a comprehensive review of the then-current knowledge of the use of exogenous hormones as growth-promoting agents covering all major livestock species, thereby updating the information provided at the 1981 RA meeting by David Armstrong. Dr Hink Perdok (UNE) presented a disturbing video titled 'Bovine bonkers'

(Perdok and Leng 1984) that revealed cattle exhibiting alarming hyperexcitability symptoms after ingesting ammoniated straw, namely, sweating, bellowing, galloping in circles and colliding heavily with other animals and fences. Ammoniation of straw to improve its digestibility was already a well-established practice (Sunstrol and Owen 1984). After filming the behaviour, Hink then discovered that similar behaviours had been documented in the USA, South Africa, the UK, the Republic of Ireland, Denmark, Sweden and Israel in 1984–1985. Disturbingly, the toxic agent responsible had been found in cow's milk. However, further investigations lead him to conclude that the likelihood of producing toxic forage can be reduced if only feeds with low soluble sugar content, such as straw, are treated and the ammonia is injected into the feed stack only when the ambient temperature is below 30°C. At the following meeting, Hink weighed up the risks and benefits of preparing ammoniated straw; he was confident to recommend the procedure but advised against the use of thermo-ammoniation (i.e. heating the treated straw in an oven to temperatures as high as 70°C).

1987 meeting

At the ninth symposium, Professor Frank Aherne (University of Alberta, Edmonton, Canada) summarised feeding strategies for maximising reproductive efficiency in gilts and sows. Professor Gene Pesti, from the University of Georgia, USA, presented experimental results that challenged the assumption that broilers given diets formulated on protein:energy ratio can adjust their feed intake to maintain a constant energy intake, regardless of dietary energy density. Extending these ideas, Gene outlined how quadratic (cf. linear) programming methods, based on the growth responses to protein and energy levels and the prices of ingredients, could enable dietary formulators to choose between diets with different protein and energy levels and still maximise profits. Drs Elliot and Kloren from the University of Queensland presented an economic appraisal of the use of sugarcane juice (in conjunction with high-fibre vegetable proteins) as the main energy source in commercial diets for monogastric animals.

Dr Keith Gregg (UNE) described his newly formed research team's innovative work that was taking advantage of recombinant DNA methods to create new rumen bacterial strains with enhanced fibre-degrading capabilities in the rumen, for example, by genetically engineering them to produce higher levels of cellulase and hemicellulase. Dr Ian McCausland, CEO of the newly formed (in July 1985) Australian Meat and Livestock Research and Development Corporation (AMLRDC) described and justified its more commercial approach to the funding of rural research. He explained that a new funding organisation had been formed to meet a perceived need by the industry and the government to put R&D on a more commercial footing and to bridge the R&D implementation gap and to cover production, processing, storage, transport and marketing. Following this, Associate Professor Keith Entwistle (James Cook University, Townsville, Qld, Australia) and Dr Peter Hopkins (QDPI, Brisbane, Qld, Australia) described a new beef cattle

research program, funded by the AMLRDC, that involved collaboration among four separate organisations in northern Australia. The concept of multi-organisational, large-group funding had arrived.

A paper presented by Dr John Ashes (CSIRO, Sydney, NSW, Australia) in conjunction with Rich Meats (*Garoon*, Baradine NSW) tackled a commercially important practical issue, namely, the flavour preferences of overseas consumers of Australian lamb. He described how grassy flavours could be eliminated by feeding special lipid supplements (manufactured from cotton seed) to grass-fed lambs in feedlots.

Dr Roy Kellaway introduced a new software package, CAMDAIRY, that was designed to assist dairy farmers, consultants, students and research workers to achieve profitable feeding management strategies for dairy cattle. Ron Leng was invited to speak in response to the publication of the first edition of his book 'Drought feeding strategies: theory and practice' (Leng 1986), in which he described some practical strategies for feeding ruminants during droughts, emphasising his balanced nutrient approach to drought feeding and, controversially, rejecting the use of more traditional feeding standards to determine energy and nutrient requirements. In his book, Ron acknowledged the influence of Reg Preston, and his colleagues in the ruminant nutrition group at UNE, on his development of feeding recommendations 'often regarded as radical by colleagues in other institutions' (Leng 1986, Preface, p. iv).

1989 meeting

At the 10th meeting, there were five invited speakers from overseas. Dr Bob Orskov (Rowett Research Institute, Scotland) introduced his audience to the many research opportunities afforded by the intragastric nutrition method (i.e. volatile fatty acids plus buffers are infused into the washed-out rumen and a protein source plus a mineral-vitamin mixture into the abomasum). This technique (see Tao and Asplund 1975) enables ruminant animals to be sustained without ingesting feed, thus removing events that normally occur in rumen digesta. Bob provided examples of how the technique had been used in different investigations, such as the absorption of volatile fatty acid mixtures, requirements for glucose and glucogenic nutrients in fasting and lactating ruminants, the extent of nitrogen secretion into the gut, and determining the optimal composition of amino acid infusates for growth and lactation.

Dr Colin Whittemore (University of Edinburgh, Scotland) described a computer-based method for determining dietary allowances for pigs selected for a high growth rate, taking into account that the potential growth rate can be restricted to levels below genetic and nutritional potential by environmental conditions, especially ambient temperature and density of stocking. Dr Rob Gous (University of Natal, South Africa) argued that pigs can often adjust their intake of nutrients themselves in response to changes in their environmental conditions and choice feeding experiments can be used to determine their nutrient requirements at their different stages of growth. Dr E. S. (Ted) Batterham (Agricultural Research

Institute, Wollongbar, NSW, Australia) discussed the limitations of cottonseed meal (e.g. low availability of essential amino acids) as a protein supplement for pigs.

Professor Harold Hintz (Cornell University, USA) reviewed the advances in knowledge of equine nutrition about to be promulgated in the fifth edition of 'Nutrient requirements of horses' by the National Research Council in the United States. Contrasting approaches to feeding management, namely, conventional feeding standards and model-based systems, were both still competing for acceptance in 1989.

Other livestock species were also covered. Dr Gillian Absolon from New Zealand described important aspects of the husbandry of the Angora rabbit and its potential development as an industry in Australia. Dr Paul Meggison (Colborn-Dawes Australia Pty Ltd) outlined how aquaculture (trout, sea trout, Atlantic salmon and prawns) had recently developed worldwide, while highlighting the potential for the development of salmonoid aquaculture in Australia. He also suggested where more research was most urgently needed. Professor Robert Moreng (Colorado State University, USA) described how the reproductive efficiency of Chinese ringneck pheasants was improved by the inclusion of brewers' dried grains in their diets.

Dr Wayne Bryden (University of Sydney, Sydney, NSW, Australia) alerted attendees to a recent stark increase in the reported occurrences of mycotoxicoses in Australia, noting that feed refusal and vomiting, hyperoestrogenism, leukoencephalomalacia, ergotism, bovine hyperthermia and geeldikkop had all been reported for the first time in the 1980s.

Dr John Moran (Kyabram Research Station, Vic., Australia) provided an extensive review of the use of silage for dairy cattle feeding in Australia. He remarked that its adoption had been much slower in Australia than overseas, probably because of our low-cost, pasture-based livestock systems. Nevertheless, John argued that maize silage can be grown on-farm for about half the cost of purchased concentrates and is generally of better quality than conserved excess pasture, the traditional supplement for Australian dairy farmers.

1991 meeting

This meeting was notable because eight of the plenary speakers were distinguished scientists from overseas and there was extensive coverage of pig nutrition.

Professor Frank Aherne (University of Alberta, Edmonton, Canada) presented an extensive review of recent research on nutrition-reproduction interactions in swine, with hypotheses about their modes of action. Dr William (Bill) Close (Close Consultancy, Berkshire, UK) suggested strategies for meeting the nutritional requirements of pigs in hot conditions, pointing out that a 1°C increase in temperature could reduce the ME intake of growing pigs by 0.76 MJ/day. Professor Paul Moughan (Massey University, New Zealand) presented two papers, one an extensive review of factors affecting amino acid digestibility in pigs and another on the related topic of amino acid losses from body tissues via endogenous secretions. Dr Jose Fernandez (National Institute of Animal Science, Foulum, Denmark) described his laboratory's approach to studies of

calcium and phosphorus metabolism in growing pigs that involved classical balance studies combined with radioactive tracers and modelling studies of calcium and phosphorus kinetics.

Drs David Filmer and David Machin (Food and Agriculture Organisation, Rome, Italy) described how feed-formulation techniques could be made more dynamic to take account of changing genetic, environmental and economic requirements on a day-to-day basis using real-time information from individual groups of animals. Professor A. J. F. (John) Webster (Bristol University, UK) outlined how he and his colleagues were attempting to improve the characterisation of both energy and organic nitrogen supply from the diet by using the software program MENTOR (Webster *et al.* 1988). The program was based on functional definitions of nutrient supply that incorporated physiological variables such as rumen outflow rate and microbial yield, elements similar to those encompassed in the rumen submodel of John Black and co-workers presented at a previous RA meeting.

Dr J. J. (Kobe) du Preez (South Africa) summarised what he considered to be the scant information available on nutrition and management of the ostrich (*Struthio camelus*). He offered some theoretical predictions for practical quantitative feeding of growing and breeding birds and made some practical recommendations for research priorities.

Keith Gregg updated delegates on the rapid progress being made by his group at UNE in characterising the genetics of rumen bacteria with the longer-term goal of introducing into the rumen genetically engineered bacteria with beneficial fibre degrading capabilities; many genes had been cloned, principally those encoding enzymes involved in fibre digestion; two rumen bacterial species had been directly transformed using recombinant plasmids; techniques had become available to allow altered strains to be monitored when returned to the rumen.

A second and significant paper was delivered by John Webster, entitled 'The science of animal welfare'. A British parliamentary inquiry into the welfare of animals in intensive livestock production systems in 1965 had focussed attention on the need for farmed animals to be able, at all times, to stand up, lie down, turn around, stretch their limbs and groom all parts of the body. In 1979, the Farm Animal Advisory Committee in the UK (later named The Farm Animal Welfare Council), at John Webster's instigation, extended this concept to encompass both physical and mental needs of animals. In his paper, Webster argued that animal welfare involves: (1) identification and analysis of the distress as perceived by the animal; and (2) what husbandry should do to alleviate the distress. He suggested the first question could be addressed by the application of logic and the scientific method; so, what the animal perceived to be problematic involves the following: (a) definition and analysis of the problem, as encapsulated by the concept of the five freedoms; (b) development of objective methods for observation, perturbation and interpretation of the welfare state; and (c) development of improved husbandry systems and management practices. The question about husbandry responses requires decisions based on less clear-cut matters of ethics and economics.

Two years after this presentation, in 1993, the 'five freedoms' concept was adopted as part of the RSPCA

Australia policy and, since then, has had an important influence on management procedures for our animal industries.

1993 meeting

Cattle feedlots attracted public attention in Australia after a heat wave in February 1991, during which more than 2681 feedlot cattle died near Texas and 217 feedlot cattle died near Condamine in Queensland (Douglas *et al.* 1991).

The organisers of the 1993 meeting invited several speakers to examine aspects of lot-feeding in cattle. Dr Bob Lee (Kantech Research Foundation, Garden City, Kansas, USA) provided a general review of feed-lotting, pointing out that an almost infinite combination of diets (high-roughage diets, high-concentrate diets, high-by-product diets), management systems and physical facilities were used in different countries. In the USA, there had been a trend towards increasingly higher concentrate inclusion to increase the efficiency of feed use, but this was profitable only if the associated increase in potential health problems was well managed. Professor Bruce Young (University of Queensland, Australia), a UNE doctoral student who had spent many years in Canada before returning to Australia, explained the physiological basis of excessive heat load (environmental heat combined with high metabolic heat production) and suggested some practical ways of ameliorating this problem. He explained that the welfare of cattle suffers most after several days of high temperature, high humidity and low air movement, in conjunction with only limited night-time cooling relief. There were several other inciteful papers given by speakers from the Australian feedlot industry.

In what would be Frank Annison's last paper at RA, Frank reviewed the options for limiting the fat percentage in animals at slaughter. These included breeding for large, late-maturing animals, feeding management and use of exogenous growth promoters. Frank observed that an immunological approach using monoclonal antibodies had been shown to successfully destroy adipocytes in rats, but required further testing before it might be used with ruminants.

Monogastric nutrition was well represented again at this meeting. Dr Kelvin McCracken (Department of Agriculture, Belfast, Northern Ireland) examined factors associated with digestive development in the young pig and the risk of enteric (mainly haemolytic *E. coli*) infection post-weaning; he pointed to the potential for ameliorating these infections using probiotics and high-fibre diets. Dr Linton Staples (Applied Biotechnologies Pty Ltd, Melbourne, Vic., Australia) described a new commercially developed amino acid supplement for use in ruminants. The product consisted of microspheres containing D-L-methionine coated with a pH-sensitive polymer that protected the methionine from degradation by rumen microbes but released it for post-ruminal absorption. He and his co-workers also presented evidence that this supplement stimulated growth and wool production in grazing weaner lambs.

Providing species variety, Professor Michael Gibney (University College Dublin, Ireland) drew the attention of attendees to the important role of fish oils in providing fatty

acids that the human body can use to create a more favourable balance in areas such as haemostasis and inflammation.

To be able to accurately determine the feed intake of grazing animals is considered to be a holy grail of ruminant research. Dr Hugh Dove (CSIRO, Canberra, ACT, Australia) described a new technique for estimating total feed intake in grazing animals using n-alkanes as markers. The n-alkanes (saturated hydrocarbons of a chain length of C25–C32) in the cuticular wax found on the leaf surface of most plants are almost indigestible and, so, are nearly totally excreted in faeces. Because the fractions of different alkanes in various plant species differ, plants (or plant parts) can therefore be categorised by their n-alkane patterns, and the mixtures of these alkane fingerprints in faeces can provide an estimate of total feed intake and the individual plant species or plant part as a fraction of the diet selected by the animal (Mayes *et al.* 1986).

David Farrell announced that this meeting in 1993 was to be his last one as principal organiser and editor of its Proceedings. He recorded his thanks to ‘all those who have over the years assisted with arrangements . . . especially Alan McKenzie and his staff at Austin College who have provided excellent accommodation, assistance and outstanding conference meals, especially the conference dinner’. He also expressed his gratitude to Ruth Fox and Janice Jopson for their secretarial and administrative assistance (Fig. 4).

The following year, David left UNE and moved to Queensland, to be followed there not long afterwards by Ron Leng. RA had lost two of its most significant contributors and supporters. The departure of both of these stalwarts of RA was, in part, a consequence of disruptions in the University system; I need to digress to explain how events occurring outside UNE were destined to challenge UNE and, in turn, RA.

Changing times: the late 1980s and early 1990s

During the 1980s, RA meetings had become firmly established but were still conducted informally. However, by the 1990s, the scientific landscape was undergoing major changes.

Prime Minister Bob Hawke had fulfilled a 1990 election promise to develop a Co-operative Research Centres (CRC)



Fig. 4. David Farrell with attendees at the conference dinner in 1993.

Program that was instigated to fund and promote industry-led (and co-funded) collaborations among industry representatives, researchers and end-users. A consequence was that research activities became more focussed, more formalised and were often performed by multiple organisations. Researchers from Universities and CSIRO formed partnerships with the business and commercial sectors to tackle multi-faceted, longer-term research problems. The CRC for Beef Genetic Technologies at UNE, which commenced in 1993 with CEO Dr Bernie Bindon, was one of the early examples of this type of research model. Individual researchers became accountable to CRC directors who often had quite specific research expectations. Speakers at RA were becoming more conscious of a need for their papers to contribute to their funding organisations and personal scientific metrics.

Universities were also facing disruption. The Honourable John Dawkins, Minister of Education in the Hawke government from 1987 to 1991 had introduced sweeping and contentious plans to amalgamate higher education institutions. In his autobiography (Farrell 2014), David Farrell remembers this period as follows:

When I returned from my secondment to Indonesia, some disturbing changes were taking place in the Australian education system. John Dawkins, the Minister of Education, was steam rolling the amalgamation of the smaller universities with colleges of advanced education (CAEs) based on student numbers. The effect on UNE was disastrous, but the local CAEs benefitted greatly. Further amalgamations with the Northern Rivers CAE 250 miles to the north and Orange Agricultural College 500 km to the south followed. Those given the task of guiding UNE and the CAEs into the hornet's nest were particularly inappropriately equipped for this task. The end came when UNE voted to de-amalgamate before the marriage was consummated, although the Armidale CAE, who came off the best, stayed in the marriage. UNE sustained incredible damage and lost some very good managers and academic staff.

The disruptions at UNE were both administrative and financial. Some senior academic staff, as already mentioned, found the changes so unsettling that they decided to retire or move on; others, such as myself, who stayed at UNE were grouped into new disciplinary clusters and confronted with financial turmoil. In 1991, UNE Armidale (there were now also UNE campuses at Orange and Lismore) had its operating budget cut by A\$3 million. The administrative and financial stringencies that followed created challenges, not only for the continuation of RA but for the survival of UNE–Armidale itself.

In the early 1990s, due in part to the evolution of research management in Australia, but accelerated by Minister Dawkin's re-organisation of the tertiary education sector and the resulting disruption at UNE, long-time RA helpers (UNE academics and support staff) found themselves re-grouped into a new Animal Science Department that was part of a new School of Environmental and Rural Science. With the shedding of support personnel, academic and

research staff were now also faced with learning keyboard and word processor skills as UNE laid off skilled typists and data-entry operators. Adjunct activities such as RA were seen as incompatible with the efficient use of funds. The flexibility of earlier days disappeared; administrative staff, who had previously had the flexibility to take part in the organisation of the RA symposia, for example, by helping with planning, typing of letters of invitation, and compiling and producing the Proceedings, if not retrenched, were now required for more narrowly defined duties.

With these disturbances and without David Farrell, Ron Leng, Bill McClymont and Frank Annison, and other loyal and experienced helpers from the Department of Biochemistry, Microbiology and Nutrition, RA was at a crossroads.

Phase 2: a new era of RA, 1995–2021

1995 meeting

Despite concerns as to whether RA would survive, the next meeting, the first of the second era of RA, was held on schedule in July 1995. It was organised by James Rowe and John Nolan with Frank Ball and Wendy Ball (skilled technical staff who had assisted in the organisation of previous RA symposia and had also been relocated to the new Animal Science Department). James had recently arrived at UNE from Western Australia to take up the position of Professor and Head of the new Department of Animal Science. The enlarged committee included staff from the disbanded Department of Livestock Husbandry who had also been moved to the new Department. Skilled computer operators, Ian Kerr and Mary-Anne Glynn, were commissioned to format the papers for the Proceedings (Table 1). With the inputs from this committed team, RA survived the disruptive changes at UNE and entered its second phase. However, future organising committees were destined to be larger than in the past (Table 1).

The presentations at this meeting were delivered in a new venue, the Wright lecture theatre in the Department of Animal Science. Five overseas scientists were invited to speak at this meeting. Dr John Oldham (Genetics and Behavioural Sciences, Scottish Agricultural College, Penicuik, Scotland) reminded the meeting that the structure of current livestock feeding systems often included minimal recognition of genotypic, environmental and behavioural factors that limit feed intake. His conceptual model of factors constraining intake (Fig. 5) described subject areas that could have been taken as a blueprint for topics at future RA meetings.

Drs Frank Dunshea and Neil Gannon (Victorian Institute of Animal Science, Melbourne, Vic., Australia) reviewed the potential for the use of metabolic modifiers including porcine somatotrophin (pST) and the more recently available, orally active β -agonists, as a means of producing high-quality lean pork. They showed that the level of response to pST depended on the dose administered as well as the genotype, sex, age and diet of the pig and the duration of treatment. Since then, pST has been registered for use in pigs by the Australian Pesticides and Veterinary Medicines Authority and Food Standards Australia and New Zealand; however, because of opposition from retailers and consumer

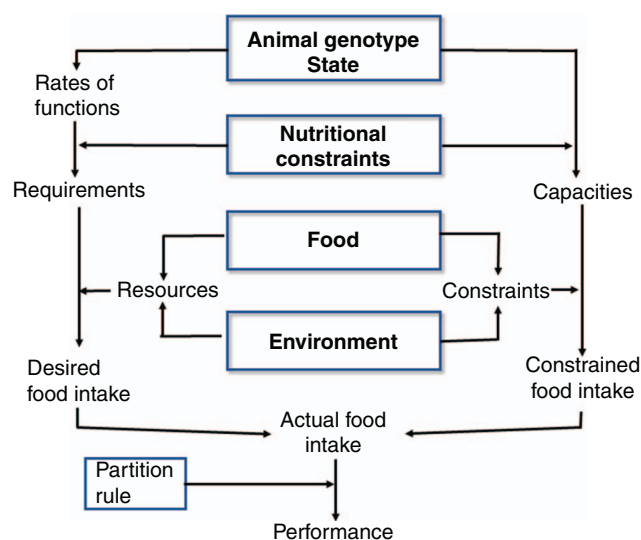


Fig. 5. Conceptual model used by John Oldham.

groups, it has not been widely adopted by industry (Dunshea *et al.* 2016).

The model AUSPIG was the subject of further evaluation by Dr Rob Smits (University of Western Australia) who used the model to show how environmental factors alter feed requirements. Dr Alison Darragh (Massey University, New Zealand) updated her audience on methods for determining amino acid availability in feeds for growing pigs.

An invited paper by Dr Bernard Carré (INRA, France) on water excretion in meat turkey poulters reminded the participants that feeding practices not only affect animal performance but can also have adverse on-farm consequences. The concepts of feed and digesta viscosity were introduced and ways of controlling the wetness of litter were canvassed. The welfare of intensively housed animals, which by the 1990s was becoming a serious social issue, was reviewed by Dr Greg Cronin (Agriculture Victoria, Australia).

This meeting was the last gathering at which one of the long-term contributors of RA, Rob Cumming, presented a plenary paper. His presentation, Nutrition/Mortality interactions in laying hens, was a research report that encompassed two of Rob's major interests, namely, nutrition/disease interactions and choice feeding. Rob's presence was a welcome reminder of earlier times and of other stalwart contributors who had moved on.

1997 meeting

The 1997 symposium was organised by Dr John Corbett (CSIRO, Armidale, NSW, Australia), with James Rowe and myself providing continuity. John Corbett's second task was as Honorary Editor of the Proceedings, a role he played until his untimely death in 2003. A newcomer to the organising committee was Dr Mingan Choct (Fig. 6) who has continued to play a major role in the organisation of RA symposia until the present day. He accepted the role of Chair of the organising committee for the next four



Fig. 6. Mingan Choct.

meetings; in addition, he has served as one of the organisers for five other meetings.

The 1997 committee decided the RA symposium had matured to a stage at which it was desirable to acknowledge the exceptional and prolonged contributions of four of its distinguished mentors by introducing four named events. James Rowe's Preface in the 1997 Proceedings (p. v) summarised the deliberations of the committee, as follows:

David Farrell was the editor and the principal organiser for most of the symposia held between 1973 and 1993. As a scientist who has worked in both ruminant and monogastric nutrition, he was the ideal convener and organiser for a symposium of this nature. The high regard in which this symposium is now held by nutritionists throughout Australia is testimony to David's commitment over the years. David's contribution to the 1997 symposium will be to present the first David Farrell lecture.

Ron Leng has always been one of the driving forces behind 'Recent Advances in Animal Nutrition in Australia'. He has played an important role in developing the ruminant side of the programs and has always contributed to the open and robust nature of the scientific debate which has become characteristic of this symposium series. In evening lectures and discussion sessions, Ron has compiled many new ideas which have challenged conventional thinking and stimulated memorable debate. His contribution in 1997 is to present the first Ron Leng lecture on Monday evening

Rob Cumming was the founder of poultry research and teaching at UNE and has contributed significantly to this field of science as well as to the success of the 'Recent Advances' series. In 1985 he was the editor and chief organiser. Rob's thorough understanding of all aspects of poultry production has gained him a level of respect in that industry which is afforded to few academics. Rob's papers have always introduced new information and ideas and have focussed on industry issues. His often provocative and persuasive contributions to discussion sessions have had an important impact on many meetings. In 1997, he has selected Bob Pym to be the first Rob Cumming lecturer. Rob will be chairing the section of the conference in which this paper is presented.

Frank Annison is widely recognised as the founding father of research and teaching in nutrition and metabolism at UNE. The group which he brought together in the 1950s and 1960s undertook pioneering research in the field of nutritional biochemistry which is still widely quoted today. With his knowledge of biochemistry, nutrition and animal production, Frank has been able to encompass the ideas of scientists who may have had too narrow a focus in their discipline and has helped others to understand important aspects of biochemistry underlying production responses. Frank is frequently invited to chair scientific meetings and has a legendary ability to stimulate debate. He has made a major contribution to numerous symposia through this skill and at this meeting Frank will be chairing the session on dairy production.

As we will see, the four people mentioned above have now been acknowledged by the establishment of named lectures.

David Farrell's named lecture was held over until the following meeting, so as to allow him to return to Armidale to present it in person. Ron Leng's designated lecture, which he delivered, was titled 'Environmental issues and their potential effects on animal agriculture towards 2005'. Ron anticipated future concerns about environmental pollution, climate change and increasing costs of feeds for ruminants that now, some 15 years later, weigh heavily on the minds of scientists and producers in Australia.

The Rob Cumming lecture was presented by Dr Bob Pym (University of Queensland, Australia). He emphasised the enormous contribution Rob had made to solving problems affecting the Australian poultry industry, involving many aspects of bird health and disease, nutrition, physiology, husbandry and management, during a career spanning more than 35 years. He reminded his audience that Rob was acknowledged as a world authority in the area of infectious bronchitis-nephritis; in addition, he was also widely admired for his work on pullet management, protein supplementation, dietary mycotoxins, the role of biotin in the treatment of fatty liver and kidney syndrome, the use of polypeepers to control feather pecking, nesting behaviour, choice feeding, nutritional control of coccidiosis, the treatment of salmonellosis using competitive exclusion principles, and the control of Newcastle disease in village chickens in Southeast Asia. Bob presented some of his observations on the opportunities and problems created by the

importation of broiler genotypes into Australia. He argued that the greater egg production of the imported broiler dam lines was countered, to some extent, by greater problems with Marek's disease and ascites in the breeders and their progeny. He also contended that more research was needed to understand the nutrient requirements of the newer genotypes when raised under Australian climatic and disease conditions.

The dairy session chaired by Frank Annison epitomised the RA spirit, with a lively discussion session following presentations by Drs Bob Fulkerson (Wollongbar Agricultural Institute, NSW, Australia), Ian Lean (Bovine Research Australasia, Sydney, NSW, Australia) and Paul Sheehy (University of Sydney, Sydney, NSW, Australia).

The other invited speakers covered various aspects of pig, poultry, aquaculture and ruminant nutrition and management. Dr Andrew Chesson (Rowett Research Institute, Scotland) described how a three-dimensional model of plant cell-wall anatomy was being used in conjunction with plant breeding to select candidate pasture plants with a high rumen degradability. Dr Mike Bedford (Finnfeeds International Ltd, Wiltshire, UK) outlined some of the factors that affect the response to xylanase in wheat-based diets for broiler chickens; Dr Geoffrey Annison (Australian Food and Grocery Council, Canberra, ACT, Australia) considered the potential for use of exogenous enzymes as a means of improving the feeding value of diets for ruminants.

Dr James Rowe (UNE) outlined the well understood reasons why acute D-lactic acidosis occurs in ruminants and horses. However, James stated 'It is suggested that a new condition, 'acidic gut syndrome' (AGS) should be recognised' in humans and other animals, because its aetiology might provide alternative explanations for behavioural changes, increased risks of gut infections, skin and respiratory conditions and other clinical conditions that, in the past, have often been attributed to food allergies or reactions to stress.

Dr David Little (Asian Institute of Technology, Klong Luang, Pathumthani, Thailand) described trends towards the intensification of land-based aquaculture (tilapia) in Asia and similarities between nutritional (and hygiene and pest management) requirements of aquaculture and those of other semi-intensive and intensive livestock production systems (cattle, pigs and poultry). Dr John Pluske (Massey University, New Zealand) portrayed factors leading to enteric diseases in pigs, horses and chickens arising from incomplete digestion and absorption of carbohydrates and presented ways of controlling these problems by prevention of acidic conditions in the gut.

1999 meeting

The papers presented to the 1999 meeting were the first to be formally refereed. Before 1999, the organisers had not seen a need to have papers refereed, believing that authors should be free to *push the scientific boundaries* and challenge their audiences with innovative ideas. However, times were changing, RA was evolving, and authors stood to benefit from being able to claim peer-reviewed publications. Twenty referees were assigned to help the honorary Editor, John Corbett, to critically review all of the papers. Their names were listed in the 1999 proceedings. Authors were also required to certify that

their research protocols had been approved by an Animal Ethics Committee. James Rowe, on behalf of the organising committee, explained the thinking behind these changes as follows:

Although refereeing involves a considerable amount of extra work, we feel that it is an important and appropriate change for two reasons. Firstly, we are aware that many papers published in 'Recent Advances' are already widely cited as if they had been refereed. Secondly, authors put a considerable amount of effort into the preparation of their papers and it is appropriate that they receive due recognition for their achievement.

A CD-ROM (ISBN 1 86389 927 8) containing all the papers delivered to RA meetings between 1977 and 1999 was prepared for this meeting by Ian Kerr and John Nolan. The CD had a search engine to enable users to find papers by author and subject, and the tables of contents were context-sensitive. The structure of the CD-ROM was designed to allow future volumes to be added (and, subsequently, a complete set of all proceedings was made available on a CD at meetings until 2005). Previous volumes had not been numbered. There were 12 volumes of the RA Proceedings already in existence when this meeting was held; however, when the 1999 Proceedings was compiled, it was mistakenly designated 'Volume 12' instead of Volume 13.

Three of the main speakers at this meeting considered the interactions between nutrition and the immune system. Professor Kirk Klasing (University of California, Davis, CA, USA) had recognised, earlier than most other scientists, that the immune system was modulated by nutrition (Klasing and Korver 1999). He pointed out, *inter alia*, that the types and ratios of polyunsaturated fatty acids had been shown to affect leukocyte function, antibody encounters and inflammatory responses to disease challenges. Eminent microbiologist, Professor James Russell (Cornell University, Ithaca, NY, USA) described how excessive grain feeding of ruminants can lead to a variety of problems (e.g. low ruminal pH, ruminitis, founder, liver abscesses) as well as the development of homolactic metabolism of *Streptococcus bovis* in the rumen and acid-resistant *E. coli* in the large intestine (Russell 1999). Dr Derek Cuddeford (University of Edinburgh, Scotland) reviewed factors affecting the safe level of starch inclusion in diets for horses after taking account of the degree of processing (Cuddeford 1999).

As planned, David Farrell returned to UNE from Queensland to deliver the lecture bearing his name. At this stage, far from being retired, David was filling two half-time positions, namely, Reader in Agriculture at the University of Queensland and Director of the Queensland Poultry Research and Development Centre in the Department of Primary Industries. He invited attendees to look forward one decade and ponder the question of 'where in the world will we find the ingredients to feed our livestock by the year 2007?' He also provided sound advice in his presentation on how to get the most from the feed we offer our livestock (Farrell 1999).

2001 meeting

The 2001 meeting was organised by a committee of veteran members chaired for the first time by Mingan Choct. Dr Roger

Hegarty, who had recently established a large-animal methane facility at UNE with joint funding from the NSW Department of Primary Industries and UNE, was a newcomer to the committee. The meeting was a particularly successful one. It was supported financially by 15 sponsors and eight of the invited speakers were from overseas institutions. John Corbett, Ilona Schmidt and 23 referees assisted with the preparation of the Proceedings. Ilona Schmidt, who had joined the organising committee when the home of RA moved to the Department of Animal Science in 1995 was singled out for special thanks for her design of this and two previous volumes of the Proceedings for which the level of presentation now exceeded contemporary printing standards and was a great improvement on earlier volumes.

Dr Jean-François Hocquette described research being undertaken by the Muscle Growth and Metabolism Group at the INRA Herbivore Research Unit, Theix, Saint-Genès Champanelle, France, to identify and study highly regulated genes such as the myostatin gene, or molecular polymorphisms that control muscle growth and meat-quality traits in cattle. Molecular regulation by under- or over-supply of nutrients and/or hormones such as insulin and thyroid hormone was thought to underpin the changes in muscle characteristics (Hocquette *et al.* 2001). Dr Frank Dunshea, who had been working for more than a decade on immunising boars against gonadotrophin-releasing factor as an alternative to castration, announced the arrival of a low-irritant vaccine, produced by CSL Ltd in Melbourne and marketed as Improvac® (Dunshea and McCauley 2001).

Dr Peter Brooks and his colleagues (University of Plymouth, Devon, UK) explained how liquid feeding of pigs can provide an opportunity to recycle liquid residues from the human food industry. Food safety can be enhanced by reducing the incidence of *Salmonella* and other enteric pathogens, especially if selected inoculants containing lactic-acid bacteria are used and fermentation conditions are carefully controlled so that an acidic diet is produced. In addition, fermented liquid feed may be a useful alternative to antibiotic growth promoters (Brooks *et al.* 2001).

Dr Katharine Knowlton (Virginia Polytechnic Institute and State University, Blacksburg, USA) reported on recent findings concerning problems associated with feeding high-grain diets to dairy cattle (Knowlton 2001) and, in the same session, Professor David Beever from the Centre for Dairy Research, University of Reading, UK, outlined feeding strategies for maximising the potential milk production from Holstein dairy herds that were, at that time, replacing Friesian herds in the UK. David argued that, if the post-calving energy intake of cows were maximised, a lifetime milk production target of 50 000 L per cow would be potentially attainable, even though probably few cows were yielding more than 30 000 L. This lifetime target would focus producers' attention on the important issue, namely heifer rearing, and, while calving at 24 months remained popular, it would be necessary to supply well grown heifers of ~600 kg liveweight with a body condition score of 3 at calving (Beever *et al.* 2001). Later, David livened up the meeting with a spirited defence of his mother country in response to my review of the mad cow (or BSE) epidemic in Britain (Nolan 2003); David

was particularly concerned by my suggestion that, in the absence of sensible measures to curb the use of meat and bone meals by ruminants worldwide, there was the potential for the spread of the human equivalent of mad cow disease, namely, Creutzfeldt–Jacob disease. It must be said that these suggestions, which David labelled 'alarmist', never eventuated, but bans placed on the use of meatmeal and bonemeal supplements for ruminants may also have curtailed further infections.

2003 meeting

The organising committee for the 2003 meeting (Table 1) was again chaired by Mingan Choct who had recently been appointed CEO of the first of two, very successful, Poultry CRCs at UNE.

For the first time, the organising committee decided to use a secure website to facilitate the online registration of participants. The website, developed by Dr Bill Pattie (Ferry Port Applications), also gave potential participants 24/7 access to meeting plans and updates.

John Corbett was again Honorary Editor and Ilona Schmidt undertook the technical editing and layout of the printed Proceedings. Mingan noted, in the Preface to the Proceedings (p. v), that the authors were, as always 'encouraged to present their ideas and data in a challenging and though-provoking manner, keeping with the tradition of Recent Advances as being an important forum for vigorous in-depth discussion of the science related to animal nutrition'. Mingan also commented (Preface, p. v), 'As in the past, our sponsors have been most generous in providing financial support for the conference and the preparation of the high-quality publication. Thank you for your continued support and confidence'. This support of sponsors enabled the committee to underwrite the attendance of seven overseas speakers.

Two of the seven speakers raised issues concerning the nutrition of wild animals. Dr Mark Edwards, a member of the Zoological Society of San Diego, explained how a lack of nutritionists with expertise on wild animal species was a global problem for zoos (Edwards 2003). Dr Mikhail Moshkin (Institute of Systematics and Ecology of Animals, Russia) reported on his collaborative studies of nutrition–stress relationships in wild rodents including the water vole (*Arvicola terrestris*) and the great gerbil (*Rhombomys opimus*) (Moshkin *et al.* 2003). His team concluded that food-related stress is sometimes actually beneficial for the survival of a species, because the death of adult animals in hard times spares the limited resources for the next generation. Dr Geoffrey Allan (NSW Fisheries, Australia) reviewed carbohydrate metabolism in silver perch and barramundi (Allan *et al.* 2003).

The potential effects of pre-natal and early life nutrition on lifelong poultry production were canvassed by Dr David Sklan (Rehovot, Israel) (Sklan 2003) and Professor John Brake (North Carolina State University, USA) (Brake *et al.* 2003). Certain problems with the use of the ileal digestibility technique for evaluating energy availability from maize-based diets for poultry were considered by Dr Tom D'Alfonso (Danisco Animal Nutrition, Wiltshire, UK)

(D'Alfonso 1914). Dr W. H. (Bill) Close (Close Consultancy, Berkshire, UK) raised some production and environmental issues associated with trace-mineral nutrition in pigs (Close 2003). Professor David Beever (University of Reading, UK) presented a paper dealing with nutritional factors required for optimal dairy production (Beever 2003).

A paper by Professor Alan Bell (Cornell University, USA) and Dr Paul Greenwood (NSW Agriculture, Armidale, NSW, Australia) highlighted a growing awareness by animal scientists of the influence of 'prenatal nutrition on postnatal development of key tissues and functions important to animal productivity, including muscle growth, reproduction, lactation and disease resistance' (Greenwood and Bell 2003, p. 68). Earlier in 2003, Professor James Rowe's paper (Rowe 2003) outlined some of the problems then being faced by the sheep industry (such as severe undernutrition for part of the year leading to reproductive inefficiency); James also foreshadowed some of the CRC's plans to use new technologies such as radio-frequency ear tags that would later facilitate automatic weighing and drafting. James had been appointed CEO of a CRC for Sheep Industry Innovation, launched at UNE in February 2002 by The Honourable Brendan Nelson, Minister for Education (and the Commonwealth CRC program). The Sheep Industry CRC was extended over three terms (18 years) with James as CEO. A book cataloging the achievements of the CRC has been published (Thomson and Rowe 2019).

2005 meeting

Mingan Choct was again the chair of the organising committee. A long-time contributor to, and supporter of RA, Dr Rob van Barneveld (Barneveld Nutrition Pty Ltd and the BECAN Consulting Group, South Maclean, Queensland, Australia) joined the committee to assist with the planning. This was the first time the committee had the benefit of an industry representative. A recently appointed lecturer in the Department of Animal Science, Dr Darryl Savage, who would later take a major role in organising RA meetings, was another newcomer to the planning team for this meeting (Table 1).

All papers were again peer-reviewed by referees and edited by Dr Pierre Cronjé and Dr Nerida Richards and Volume 15 was prepared as a book and a CD-ROM. A second CD-ROM carrying all 15 of the Proceedings of RA meetings was also produced and dedicated to John Corbett (Fig. 7) who died in December 2003. John had been a long-time contributor to RA and Honorary Editor of Volumes 14 and 15 of the Proceedings. In the Preface to Volume 15 (p. v), Mingan Choct commented

John was a regular contributor to *Recent Advances* since its inception ... and acted as an honorary editor from 1997 to 2003. John was highly professional, extremely sharp-witted and had a special sense of humour. To celebrate John's life-long dedication to nutritional science and honour his outstanding contribution to *Recent Advances*, this year we will present the inaugural *John Corbett Prize* for the best, contributed paper.

A seminal paper at this meeting was delivered by Dr Nigel Scollan (Institute of Grassland and Environmental Research,



Fig. 7. John Corbett.

Aberystwyth, Wales, UK) that embodied the newly coined phrase 'functional foods', a generic term used to describe foods or food components that have beneficial effects for human health, above those expected on the basis of their nutritive value (Scollan and Huws 2005). Nigel described how the concentrations of two functional food components in beef meat and milk, namely, omega-3 polyunsaturated fatty acids (PUFA) and conjugated linoleic acid, could be manipulated by diet 'with the proviso that as the dietary content of omega-3 PUFA is increased, undesirable 'greasy' and 'fishy' attributes develop and 'the colour and shelf life of the product may be reduced', necessitating the use of higher levels of dietary antioxidants.

Dr George Kamande (Diamond V Mills, Cedar Rapids, IA, USA) described recent research (conducted with collaborators in Australia) on the effects of dietary supplementation with a yeast culture on dairy cows and calves (Kamande *et al.* 2005). Only one of the two trials he reported showed improvements in milk production, a portent of the ambivalent conclusions obtained from more recent work with yeast supplementation.

A long-standing question, namely 'can we improve the efficiency of nitrogen utilisation in the lactating dairy cow?', was revisited by Dr G. A. Harrison (Alltech Biotechnology Centre, KY, USA) who recommended that future research efforts should focus on optimising microbial protein synthesis and improving the efficiency of milk production (Harrison and Karnezos 2005).

As participants have come to expect of RA, this meeting examined nutritional issues relating to less-studied species. Dr Meegan Vandeppeer (Barneveld Nutrition Pty Ltd, South Maclean, Qld, Australia) outlined the difficulties for the

Australian abalone industry posed by restrictions on the use of algae as a source of nutrients, making abalone farmers entirely dependent on manufactured feeds (Vandepeer and van Barneveld 2005). Meegan described how terrestrial nutrition principles and alternative feed sources were being used to cost-effectively promote high growth rates of farmed abalone.

2007 meeting

For the RA meeting held in 2007, the organising committee had a new chairperson, Dr Darryl Savage, and included some other new faces (Table 1).

All the plenary articles were again independently peer-reviewed and the Proceedings edited by Dr Pierre Cronjé. The one-page papers were edited by Dr Nerida Richards, but not otherwise peer-reviewed.

As always, the organisers of the 2007 meeting had been on the lookout for speakers with new ideas and approaches to animal production specialising in related fields of endeavour. Their efforts were rewarded when they invited Dr David Raubenheimer (then at the University of Auckland, New Zealand but, since 1913, the Leonard P. Ullmann Chair in Nutritional Ecology at the University of Sydney, NSW, Australia) to introduce a novel modelling technique called 'the geometric framework'. He explained the framework was developed in the context of questions arising from the nutritional ecology of a range of taxa, spanning insects, spiders, fish, birds and mammals (including humans) and it enabled key nutritional dimensions to be identified, and the environment, the animal and the animal–environment interactions to be represented and related to performance outcomes (Raubenheimer and Simpson 2007). The rigour of this approach was similar to that applied by the whole-animal nutritional modellers to manage the nutrition of farmed livestock.

When considering fermentation in an animal-production context, most nutritionists would think first of the rumen, or perhaps silage making. However, Dr Dianne Ouwerkerk (Animal Research Institute, Yeerongpilly, Qld, Australia) caught the attention of the audience with an explanation as to why kangaroos do not produce methane even though they ferment fibrous feeds in the same way as ruminants (Ouwerkerk *et al.* 2007). Dianne provided evidence that the stomachs of macropods support microbial populations that use reductive acetogenesis (acetic acid production) as an alternative to methanogenesis, thus capturing the hydrogen produced during fermentation. In a companion presentation, Drs Barbara Williams and Mike Gidley (University of Queensland, Australia) drew attention to the importance of the end products of enteric fermentation (e.g. butyric acid) for the health of the pig, especially in the post-weaning period when diarrhoea syndromes can lead to economic loss (Williams and Gidley 2007). Barbara also described a potential role for dietary supplements, including prebiotics, in preventing such diseases.

As usual, poultry nutrition was well represented at this meeting. Dr Harald Hetland (Norwegian University of Life Sciences, Ås, Norway) presented research findings that would

have been music to the ears of the late Rob Cumming, namely, explaining how litter consumption by poultry stimulates gizzard development and thus improves feed passage regulation, pancreatic secretion, nutrient digestibility and gut health (Hetland 2007).

Continuing the feeding behaviour theme from earlier RA meetings, Dr Justin Lynch (CSIRO, Chiswick, NSW, Australia) explained how sheep use vision, touch, olfaction and taste to recognise dietary components and argued that this sensory identification process, when associated with the metabolic consequences of ingesting different feed components, determines their overall feed choices (Lynch and Hinch 2007). He concluded that a better understanding of these events might help reduce the among-sheep variation in diet selection that is often a problem when animals are offered feed supplements.

2009 meeting

Because of the demands on space from people wanting to attend RA meetings (by then exceeding 120 delegates), Darryl Savage and his committee decided to move the 2009 meeting to a new venue at UNE. The Duval College Conference Centre was engaged to host the symposium; the College dining hall was the venue not only for meals but also for the presentations.

During the planning, the symposium somehow acquired a subtle change in title from 'Recent Advances in Animal Nutrition in Australia' to 'Recent Advances in Animal Nutrition – Australia'. This change was not planned and it slipped by largely unnoticed until later. The altered name of the Proceedings volume affected its library cataloguing, but otherwise was probably of little consequence.

A key speaker at this meeting was one of the long-time participants and supporters of RA, A. C. (Tony) Edwards (ACE Livestock Consulting Pty Ltd and the BECAN Consulting Group Pty Ltd, SA, Australia). Tony's presentation was titled 'Significant breakthroughs in pig nutrition during the past 30 years and future challenges' (Edwards 2009). Tony looked back at more than 400 plenary papers presented at RA conferences since 1974 and noted (p. 113) that it was 'easy to overlook significant breakthroughs that were first posed or developed within this forum and have become common practice for nutritionists across the world'. These innovations included the development of the ideal protein concept, improved characterisation of amino acids, the relationship between protein, energy and growth, application of supplementary enzymes, development of mycotoxin binders, use of metabolic modifiers and measurement of feedstuff quality using near infrared reflectance technology. He listed topics worthy of further investigation including management of the differential digestion rates of nutrients from various sources (nutrient asynchrony), immunity \times nutrition interactions, roles of specific amino acids in processes other than tissue accretion and alternative ways of exploiting liquid feeding regimens. Looking to the future, Tony predicted (p. 113) that 'there will be sustained pressure on livestock producers to reduce environmental impacts and optimise animal welfare; the pursuit of advances in nutrition will be fundamental to the

sustainability of pig production; and the RAAN forum will remain a key vehicle for delivering new technologies to nutritionists'.

Recalling past RA meetings, Tony noted some particular highlights, including:

- quantification of the relationship between protein and energy for pig metabolism and growth by the Werribee Group, e.g. Campbell (1987), that resulted in a significant change in diet formulation procedures (p. 114);
- exogenous porcine somatotrophin, 'possibly the most performance-enhancing technology to emerge during the past 30 years'; initial research in the USA on porcine somatotrophin and subsequent evaluation by the Werribee Group (Campbell *et al.* 1990a, 1990b) resulted in commercially available Reporcin® (p. 115);
- the development of robust near-infrared calibrations for analysing the digestible energy value of cereals for pigs (van Barneveld *et al.* 1999);
- vaccination against gonadotrophin-releasing hormone, developed in Australia, to address the long-standing problem of boar taint in entire male pigs (the development of gonadotrophin-releasing hormone was reported at RA in 2001; Dunshea and McCauley 2001) and is now being widely applied in other species; adoption of the commercial vaccines has increased to ~75%);
- recognition of immunity \times nutrition interactions and that mounting an immune response consumes available nutrients that would otherwise be available for productive purposes and may suppress feed intake (Klasing 1996);
- contributions of exogenous enzymes to making better use of limited feed resources.

For ruminant nutritionists at the meeting, Dr D. R. (Dave) Davies (Gogerddan Campus, Aberystwyth University, Wales, UK) described the significant advances in silage-making technologies during the past 30 years, particularly with silage additives, that can reduce aerobic deterioration and improve fermentation and resulting nutritional quality (Davies and Smith 2009). Technologies that reduce the detrimental effects of mycotoxins at feed-out time were also discussed. A paper on the value of ensiled high-moisture grain for livestock feeding by Drs Harry Miettinen and Lily Li (Asia Pacific Pty Ltd, Singapore; delivered by Lily Li) encouraged participants to consider the nutritional and cost advantages of including ensiled high-moisture grains in ruminant, pig and poultry diets (Miettinen and Li 2009). The reason for this recommendation was that high-moisture ensiled barley has a higher digestibility for pigs and poultry than that of dry barley because of its lower content of β -glucans and phytate phosphorus and a higher content of lactic acid.

Dr Alex Péron (Danisco Animal Nutrition, Marlborough, Wiltshire, UK) reviewed recent trends in supplies of raw feed materials and factors affecting the nutritive value of cereal grains and their by-products, and also of legume seeds and protein meals (Péron and Partridge 2009). Alex also described how exogenous enzymes can be used to improve both the quality and value of feed. Dr Aaron Cowieson (AB Vista Feed Ingredients, Marlborough, Wiltshire, UK) summarised the effects of dietary inclusion of xylanase and phytase on ileal

amino acid digestibility in pigs and poultry and pointed out that the activity of these enzymes is additive, seldom 100%, but predictable nevertheless. Dr Ray King (RHK Consulting Pty Ltd, Vic., Australia) supported the use, at low dietary inclusion rates, of by-products from ethanol and biodiesel production such as dried distillers' grains with solubles, feed-grade glycerine and oilseed meals as cost-effective nutrient sources for Australian livestock (King 2009).

A new paradigm for monogastric animal nutrition aimed at improving animal production was presented by Dr Mark Geier (Pig and Poultry Production Institute, Roseworthy Campus, SA, Australia) (Geier 2009). It involved 'feeding genes' via microbiota-containing additives to alter the intestinal environment and the interrelationships among the mucosal immune system, mucin dynamics and gut structure.

Dr R. A. (Bob) Hunter tackled an emerging issue for ruminant nutritionists, namely, how to minimise the release of the greenhouse gas, methane, from cattle herds; his modelling highlighted the importance of shortening the calving interval for cows and increasing the rate of growth of weaner cattle to slaughter weight, so as to minimise the methane produced per unit of retail beef (Hunter and Niethe 2009).

2011 meeting

The organising committee for this meeting was chaired by Dr Pierre Cronjé with Mingan Choct as co-Chair and was the last of a series of seven successive meetings with Mingan playing a major role in the planning group. Recently, in a letter to me describing the period from 1997 to 2011, Mingan observed that:

nutritional problems had become more complex and a single-pronged approach could no longer offer solutions. Gut health, for example, had become a major focus and studies of the gut needed not only nutritional approaches but also genomics, microbiomic and immunological tools to unravel the issues raised. RA went back to the basics and multi-disciplinary research became more common. At the same time, Industry was becoming less interested in soft promotion of its products and more keen to have researchers study complex issues they could not unravel themselves.

The RA organisers enlisted the help of Australia's CRCs and commercial partners to help identify relevant topics for the 2011 program. They decided to focus on the future availability of global feed sources and strategies enabling more efficient use of these resources. Other topics nominated included greenhouse gas emissions, environmental pollution, nitrogen recycling and biofuel production. These were critical issues in 2011 and progress towards solving them since then has been far too slow.

In the Preface to the 2011 Proceedings, Pierre Cronjé observed that:

for most of the twentieth century, the research agenda was dominated by strategies aimed at increasing the level of animal production, and less attention was paid to the efficiency with which this was achieved – as long as

net profit improved. This is understandable when one considers that this period coincided with the Green Revolution which transformed agriculture around the globe and resulted in a 250% increase in world grain production between 1950 and 1984. At that time, no one would have ventured to predict that by 2011, 40% of the US maize crop would be used to produce fuel for automobiles and that the price of oil would affect the price of livestock feed. It is evident that improvement in feed conversion efficiency has risen to the top of the contemporary research agenda, and the contributions in this volume show that the livestock industry is eminently capable of increasing the supply of animal products without harming the environment, notwithstanding the dwindling availability of feed grains.

Professor Robert (Bob) Swick (Fig. 8) had recently arrived at UNE and joined the organising committee for this meeting. Later, he became the Chair of the organising committee and the face of RA for its next five meetings and served on two other RA organising teams. A native of the USA with a wide experience in poultry nutrition and product development in the commercial world, Bob provided the delegates with a global perspective on grain resources (Swick 2011). He pointed out that the human population was predicted to rise from 7 to 9 billion by 2050; yet, increasingly, feed-grain resources were being diverted towards biofuel production (the European Union had already mandated that 20% of the fuel used for transportation would be biofuel by 2020). Bob predicted this trend would lead to a demand-driven increase in the cost of grain for human food and livestock production.

Dr Marc de Beer (DSM Nutritional Products, Parsippany, NJ, USA) posed the challenging question: ‘is a feed conversion

ratio of 1:1 a realistic and appropriate goal for broiler chickens in the next 10 years?’ (de Beer *et al.* 2011). It was certainly a desirable goal but, with the wisdom of hindsight, perhaps not a realistic one. Nevertheless, it was the kind of aspiration RA should continue to applaud.

Ten of the remaining 12 plenary papers were presented by invited Australian scientists, focussing on factors affecting the efficiency of animal production. The quest for more feed-efficient pork production was tackled by Dr Bruce Mullan (Livestock Industries Innovation, Perth, WA, Australia) and Professor Frank Dunshea (Pork CRC and the University of Melbourne, Australia) (Dunshea *et al.* 2011; Mullan *et al.* 2011). Professor Mike Goddard (University of Melbourne) and Dr Rob Herd (CRC for Beef Genetic Technologies, Armidale, NSW, Australia) suggested that genetic selection of beef cattle on the basis of their residual feed intake offered opportunities to increase their feed conversion efficiency (Goddard *et al.* 2011; Herd and Pitchford 2011).

Another of the invited papers, by Dr Christian Lückstädt (ADDCON Europe GmbH, Bonn, Germany), considered the use of organic acids (especially potassium di-formate) as feed additives for poultry and fish, to replace antibiotics and also increase the efficiency of assimilation of protein and phosphorus (Lückstädt and Mellor 2011). The search for new and effective feed additives had been on the research agenda for some time, promoted by an EU-wide ban on the use of antibiotics as growth promoters in animal feed that had come into effect 1 January 2006.

The papers from the 2011 meeting made up Volume 18 of the RA Proceedings, which was the last volume to be published in-house by the Department of Animal Science at UNE. The editing, design and layout were undertaken by Pierre Cronjé and the printing and binding by the UNE printery.

2013 meeting

The theme for this meeting, ‘Tomorrow’s nutrition today’, was designed to cover topics related to the meat and companion animal industry that will shape nutrition research and feed ingredient demand in the foreseeable future. The organising committee decided, so as to expose both the conference and the authors to a wider audience, to publish the manuscripts of invited speakers in a special issue, Volume 53, of the CSIRO journal, *Animal Production Science*. Pierre Cronjé was the guest editor.

Bob Swick listed some consumer-driven issues deserving coverage at this and future meetings (Preface, p. iii). He labelled them ‘today’s realities’, and they included the following:

- free-range poultry production;
- group housing of sows;
- hormone-free animal products;
- recognition of the carbon footprint of animal production; (and)
- animal feeds without meat meal or GMO (genetically modified) ingredients or antibiotics.

The presentations at this meeting were delivered in another new venue, the large lecture theatre in the Education Building at UNE. There were 15 invited papers, three presented by overseas speakers.



Fig. 8. Bob Swick.

Bob also suggested (Preface, p. iii) that ‘rapid feed-ingredient analysis, feed processing to enhance digestibility, alternative formulation systems for poultry, estimating pasture intake and improving phosphorus and amino acid utilisation in ruminants’ would help improve the efficiency of production in various animal species while keeping consumer trends in mind. Nutritional strategies to enhance the health and well being of companion animals would also be important considerations for the future.

Dr Y. G. (Kevin) Liu (Addiseo Asia Pacific, Singapore) directed his audience to extend their existing dairy protein nutrition considerations beyond rumen-degradable protein and undegraded dietary protein (also termed bypass or escape protein) to embrace the two most limiting essential amino acids, methionine and lysine. He explained that enhancing the availability of these amino acids by, for example, supplementing cows with protected methionine sources (in addition to blood or fish meal, soya bean and canola meal) had been shown to improve milk production as well as cow health and reproductive efficiency (Liu *et al.* 2013).

The other two overseas speakers were from the UK. Professor Julian Wiseman who was, for many years, the editor of the publications from the ‘Recent Advances in Animal Nutrition’ conferences held at the University of Nottingham, presented a detailed account of the characteristics of various feed starches and the importance of understanding the effects of different processing methods (Wiseman 2013). Dr Hadden Graham (AB Vista Feed Ingredients, Marlborough, UK) described how the use of near-infrared spectroscopy could be extended beyond feedstuff evaluation to enable real-time and in-line feed analysis, thereby giving more reliable predictions of feed costs and enhancing the profitability of animal industries (Hadden *et al.* 2013).

Professor Simon Bailey (University of Melbourne, Vic., Australia) described the metabolic responses of horses and ponies to high and low glycaemic feeds and discussed how these feeds are linked to laminitis. Dr Lily Li came again from Singapore to deliver a paper on the effects of dietary nitrate and elemental sulfur on wool growth and methane emissions in sheep (Li *et al.* 2013). Professor David Cottle (UNE) highlighted the many difficulties associated with the estimation of pasture intake by grazing ruminants. Despite the promise offered by Hugh Dove’s innovative alkane marker research unveiled at the RA meeting in 1993, David concluded that estimation of the intake of pasture by grazing ruminants remains one of the ‘brick walls’ in ruminant research (Cottle 2013).

Two of the other invited speakers examined how misguided public opinion can affect livestock producers. Professor Neil Mann (RMIT University, Melbourne) discussed the important role that meat has played in human nutrition throughout history supplying, *inter alia*, protein and long-chain omega-3 fatty acids, despite unscientific claims of a vocal minority of the public that humans evolved eating vegetarian diets (Mann 2013). This was followed by a lively presentation by Dr Ian Lean (SBScibus, Camden, NSW and Adjunct Professor, University of Sydney) who alerted delegates to the way supermarkets were unscientifically shaping consumer beliefs

and preferences, with the consequences being borne by the producers who supplied them. Ian characterised the unilateral ban, introduced by one major supermarket chain in Australia, on the use of hormonal growth promoters by beef producers as a dangerous development, ‘in which marketing ploys have been accorded a higher value than the care of animals, the environment, or the profit made by producers’ (Lean 2013, p. 1143).

2015 meeting

The theme of this meeting, ‘Early nutrition for long-term animal productivity’, was chosen as a way of promoting the exchange of ideas across animal species; speakers presented the latest findings on mineral and vitamin nutrition, epigenetics, nutrigenomics, placental and embryonic nutrient flow and potential benefits of pre-starter and creep feed modifications. The invited papers were published in a special issue of *Animal Production Science* (Volume 56).

At this meeting, the organisers instigated the McClymont Rural Science Review. Named after Bill McClymont, this lecture was to be presented at all future meetings by an eminent scientist on a topic of their choosing. The presenter in 2015 was Professor Alan Bell (Cornell University, USA), a BRurSc(Hons) graduate from the Faculty of Rural Science founded by Bill at UNE. In keeping with the 2015 RA ‘early-life nutrition’ theme, Alan reviewed current knowledge of the prenatal origins of postnatal variation in growth, development and productivity of ruminants. He and his co-author, Dr Paul Greenwood (NSW Department of Primary Industries Beef Industry Centre, UNE) highlighted recent research, undertaken since their comprehensive review presented at the RA meeting in 2013, showing that prenatal nutrition can influence postnatal growth, body composition, wool growth and reproductive performance in sheep and cattle. In general, the consequences for production seemed small relative to the effects of post-natal nutrition and other environmental influences. Nevertheless, they argued that the magnitude and persistence of prenatal effects, including those mediated by epigenetic modifications of the genome (that were probably subject to inter-generational transmission) needed to be better understood and quantified (Bell and Greenwood 2016).

Professor Phil Hynd (University of Adelaide, SA, Australia), also a BRurSc(Hons) graduate from UNE, explained how the environment of a developing chicken within the egg can program its development and lifetime health and production; he also reminded his audience that the modern broiler chicken spends 40% of its life developing in the egg (Hynd *et al.* 2016). Dr Alex Chang (Aviagen Group, AL, USA) noted the well documented effect of nutrition on broiler breeders’ live-weight profile, and egg characteristics; he concluded that a diet low in crude protein and medium to high in energy, given throughout the rearing and laying period, would not only have a positive effect on egg production, egg size, breeder fertility, hatchability and embryonic liveability but also on the performance of offspring, with male broilers responding more than female broilers. There was good evidence of direct effects of vitamins D

and E, and trace minerals such as selenium, zinc and manganese (especially in organic forms) on chick quality and subsequent performance (Chang *et al.* 2016).

Professor Hans Stein (University of Illinois, Urbana, IL, USA) described the results of two experiments conducted at his university to test whether reducing the particle size of ground maize (corn) would improve its digestible energy content when offered to weanling pigs. The experiments also tested whether there were improvements in energy and nutrient digestibility and weanling performance due to extrusion or pelleting, or extrusion and pelleting of diets that contained low, medium or high levels of fibre. The results indicated that feed-to-gain efficiency of pigs offered diets containing maize increased as the particle size was reduced and, for high-fibre diets, extrusion seemed to improve energy availability (Rojas and Stein 2016).

Dr Carrie Walk (AB Vista, Marlborough, Wiltshire, UK) recommended caution when formulating pig or poultry diets containing phytase, to minimise possible adverse effects of over-supply of calcium on chemical and physical conditions in the gut that, in turn, could affect dietary phytate solubility, nutrient digestibility, and phytase efficacy (Walk 2016).

In his last presentation at RA, Dr Hugh Dove (CSIRO, Canberra) spoke about the mineral nutrition of livestock. He and his co-authors reviewed the available information on how well winter-grazed cereal and canola crops met the requirements of young livestock and concluded it would be prudent to provide sodium and/or magnesium supplements for young livestock grazing wheat (and possibly oats and barley) and calcium supplements for livestock grazing oats or, in the case of reproducing animals, when grazing all three cereals (Dove *et al.* 2016). Interestingly, grass tetany was not observed in any of the studies, even though it is considered to be an early sign of magnesium deficiency, so the clinical symptoms observed may not have been related to magnesium deficiency *per se* but to an interaction between magnesium and other nutrients (Masters 2018).

2017 meeting

The organisers of this meeting decided to create another named lecture, the Annison–Leng Oration, to applaud the contribution to ruminant nutrition and to RA of former UNE academics, Emeritus Professors Frank Annison and Ron Leng (Fig. 9). As noted earlier, Frank Annison was an international leader in the nutritional biochemistry of ruminants. His contributions were recognised in 1990 when he became the fifth recipient of the International Roche Research Prize for Animal Nutrition ‘for outstanding research in a variety of fields of mammalian biochemistry and nutrition but particularly for his contribution to quantitative nutritional knowledge relating to milk production by the lactating dairy cow’ (Armstrong 1990, p. 13). The citation made special reference to Frank’s pioneering studies employing isotope dilution techniques to quantify intermediary metabolism in sheep and mammary metabolism in cows. He was later awarded Fellowships of the Nutrition Society of Australia in 1991, the Australian Society of Animal Production in 2002 and Membership of the Order of Australia in 2004 (Bell 2019). Frank’s first PhD student at UNE was Ron Leng who, throughout his distinguished career, made major contributions to improving the nutrition of ruminants in Australia and the developing world. Ron Leng was invited to deliver the first lecture in this series and he took the opportunity to highlight the critical role of biofilms in nature, and more particularly within the rumen microbiome; it was a topic he had been developing and promoting for many years (Leng 2014). His paper emphasised the role played by the complex microbial communities within biofilms in the detoxification of potentially deleterious plant toxins ingested by ruminants (Leng 2017).

Professor Lewis Kahn (UNE), another BRurSci(Hons) graduate and one of Ron Leng’s PhD students, introduced his audience to a new web-based program called ASKBILL (another tribute to Bill McClymont) that was developed to assist sheep producers to enhance the well-being and



Fig. 9. Frank Annison and Ron Leng.

productivity of their flocks (Kahn *et al.* 2017). ASKBILL was developed within the Sheep Industry CRC and released in March 2017 (and has undergone further development since then). ASKBILL provides a simple interface linking several complex biophysical models that are customised by user inputs, localised daily weather updates and a dynamic probabilistic 90-day climate forecast. These features minimise the requirement for manual, auto and remote measurements, thus reducing labour requirements and complexity. The program's dynamic predictive capacity also enables it to provide early alerts to users when production targets are unlikely to be met.

The McClymont Review was delivered by Professor John Furness (University of Melbourne, Vic., Australia). John presented a comprehensive review of the intricate mechanisms that exist in the gut of animals and enable the host to defend itself against pathogens and chemical challenges, while still efficiently absorbing vital nutrients (Furness and Cottrell 2017). This presentation set the scene for a lively session in which five overseas and 10 Australian speakers covered topics relating to communication between the intestinal mucosa and its digesta; associations between mitochondria and meat quality and the potential for the production (and acceptability) of artificial meat; and recent advances in starch, amino acid, calcium and phytase nutrition across the poultry, dairy and pig industries. There was also further consideration of feeding strategies aimed at promoting gut health without the use of antibiotics. Bone health in horses was reviewed by Professor Brian Nielsen, Michigan State University, USA (Nielsen *et al.* 2017) and phosphorus metabolism in cows and poultry were also discussed.

The 15 invited papers delivered at this meeting were published in Volume 57 of *Animal Production Science*.

2019 meeting

While this meeting was being planned, farmers in many parts of Australia were suffering from a drought that had restricted their production of grains and protein meals. At the same time, trade restrictions between the USA and China were affecting the supply of imported feeds, particularly soybeans, which are a major protein source for Australian livestock. Protein-supply issues had stimulated interest in the use of alternative protein sources and also the more strategic use of crystalline amino acids. The disrupted global soybean supply coincided with an increased demand for locally produced pork in response to the outbreaks of swine fever in China, Vietnam and other Asian countries. In light of these contemporary events, the organisers encouraged speakers to focus on feed protein and its efficient use into the future.

Dr Julian McGill, with co-workers David Jackson and Martin Todd (LMC International Ltd, Kuala Lumpur, Malaysia) and also Dr Amy Moss and Robert Swick (UNE), gave their predictions on future global trends in grain and oilseed production. They predicted that there will be a contraction in the area planted to cereal crops and an increase in oilseeds production as the demand for food for humans and livestock becomes the main driver for global agriculture (McGill *et al.* 2019).

Jessica de Souza-Vilela, a PhD student and her co-authors from UNE, pointed out that insects such as the black soldier fly larvae (*Hermetia illucens*), crickets (*Gryllus testaceus* Walker) or mealworms (*Tenebrio molitor*) may become valuable alternative sources of energy, protein and fat in diets for livestock (de Souza-Vilela *et al.* 2019). This idea was echoed by Dr Kirsty DiGiacomo and her colleagues from the University of Melbourne. Kirsty highlighted the current global interest in insect feed sources and described her studies of black soldier fly larvae aimed at achieving sustainable bio-production of animal feed via the conversion of food wastes into edible insects. Moreover, she pointed out that insects also have nutraceutical properties that may have beneficial impacts on animal health and growth, with scope for these properties to be exploited as feed or food additives (DiGiacomo *et al.* 2019). Other speakers suggested strategies for improving the efficiency of dietary protein use by animal tissues.

Professor Gordon Lynch (University of Melbourne, Vic., Australia) presented the McClymont lecture and applied nature's paradox to skeletal muscle (that fibre size and oxidative capacity are mutually exclusive); he argued that, by better understanding the nature of the regulation of muscle size and phenotype, and by selectively manipulating biological signalling, scientists might unlock the paradox and produce both larger and more oxidative muscles (Lynch and Koopman 2019).

Two excellent reviews on amino acid metabolism in sows (Zhang and Trottier 2019) and horses (Trottier and Tedeschi 2019) were presented by Professor Nathalie Trottier, Michigan State University, East Lansing, USA.

Dr Hutton Oddy (NSW Department of Primary Industries, Armidale) presented the Annison–Leng Oration, in which he described a modelling strategy that provided estimates of the energy cost of protein deposition in ruminants and elucidated the underpinning mechanisms that link protein and energy metabolism (Oddy *et al.* 2019).

Another named lecture, the Cumming–Farrell Oration was introduced at this meeting (Fig. 10). In the Foreword of Volume 59 of *Animal Production Science*, Bob Swick explained the reasons as follows:

The Cumming–Farrell Oration celebrates the contribution of Professor Rob Cumming and Professor David Farrell to non-ruminant nutrition and to their roles in the establishment of RAAN-A. Rob Cumming and David Farrell, respectively from South Africa and Ireland, established UNE as a leading site of poultry nutrition research in Australia. Rob was also a noted avian virologist and David also worked with pigs, especially amino acid digestion. Both Rob and David made numerous contributions to improving the nutrition and health of poultry and pigs in developing countries.

The inaugural Cumming–Farrell Oration was titled 'Associations between gastrointestinal tract function and the stress response after weaning in pigs' and presented by Professor John Pluske (Murdoch University, Western Australia). It was a commanding sequel to his McClymont Review at the previous RA meeting, extending discourse on the importance of gut



Fig. 10. Rob Cumming and David Farrell.

metabolism in relation animal production (Pluske *et al.* 2019).

2021 meeting

The 23rd symposium in the RA series will be unique for at least two reasons. For the first time in the history of RA, the organising committee has decided to experiment with holding the meeting away from the UNE campus. Because of the COVID-19 pandemic, also for the first time, it has not been feasible to bring speakers from overseas. Nevertheless, the program will include a number of eminent Australian scientists.

The McClymont Rural Science Review will be given by Professor Mike Gidley (University of Queensland, Brisbane, Australia) who will draw lessons from a Decadal Plan for the Science of Nutrition recently published by the Australian Academy of Science (NCN 2019). I will deliver the Annison-Leng Oration using the information in this history of RA. The Cumming-Farrell Oration on probiotics in an antibiotic-free farming environment will be presented by Dr Shaniko Shini (University of Queensland, Brisbane, Australia). Because of COVID-19 travel restrictions, again for the first time, it will be possible to take part in the meeting interactively from anywhere in the world via an Internet connection.

We are riding the COVID pandemic in uncertain times but is clear the movement of people around the globe and the world economy will be affected for years to come. This RA symposium will therefore mark another watershed in our history. It is an appropriate juncture for participants at this meeting, and the alumni of RA, as we face a number of existential challenges, to take stock and plan a course for RA in the decades ahead.

Future livestock-feeding challenges

The prevailing discourse on the future of agriculture is dominated by an imbalanced narrative that calls for food

production to increase dramatically – potentially doubling by 2050 – without specifying commensurate environmental goals (Hunter *et al.* 2017, p. 386).

Currently, ~70–80% of Australia's total agricultural production is exported (about one-third of this to China) and only ~20–30% is consumed locally; however, even with this surplus, ~15% of Australia's daily food supply is imported (NFF 2018). Despite the effects of drought and the Covid 19 pandemic, Australia exported A\$50.1 billion worth of agricultural produce in 2019–2020, of which A\$27 billion was generated by farmed livestock (Rural Bank 2021). Looking towards 2050, the demand for food is projected to increase as the global population approaches 9.7 billion and higher living standards will further increase the demand for animal products (Hunter *et al.* 2017).

To increase farm production to take advantage of the expanding global markets for livestock products, Australian livestock producers will need to source additional feedstuffs, most likely from broad-acre crops. However, cropping is already putting pressure on increasingly scarce arable land and water resources and, in addition, is degrading the environment. Cereal products represent only ~13% of the total feed intake of the world's farmed livestock, yet farm animals consume nearly one-third of the current global cereal production. Even with some further increases in feed conversion efficiency, the global demand for grain and other crop products for livestock feeding (and biofuel production) will continue to grow and the costs of feeds for livestock will increase accordingly (OECD–FAO 2020). Higher costs of grains will create challenges for ruminant production in feedlots as well as the pig, poultry and other livestock industries.

The challenges are real and immediate, and the tipping points are probably closer than we would like. In the main, papers presented at RA have tackled technical problems

(e.g. least-cost diet formulation). In the future, the RA community will also need to tackle the wider resource, environmental and societal issues. For example, the use of cereals and soybeans for feeding animals when they would be used more efficiently if consumed directly by human beings is, and will continue to be, challenged on ethical grounds (the food versus feed debate; McClymont 1976; Mottet *et al.* 2017). Speakers will need to address the public's growing concern about the livestock/environment nexus and suggest solutions to the question of how we can meet the increasing demands for feed and water for our livestock without increasing their environmental footprint. The capacity of the RA participants to pro-actively advance methodologies that increase production while maintaining environmental sustainability will ultimately determine its future effectiveness.

Climate change and agricultural sustainability issues will dominate crop and livestock producers for the foreseeable future. Waterway and ocean pollution and release of nitrogen oxides to the atmosphere caused by inefficient on-farm capture of nitrogen from protein-rich feeds and fertilisers will need to be better recognised and addressed. The use of fossil fuels to power tractors and transport feeds, livestock and food products (often long distances by ship) is becoming increasingly problematic. The release of enteric methane, a potent greenhouse gas, and the high requirements for water per kilogram of meat produced will continue to be a source of censure for the ruminant industries (Cottle *et al.* 2011). Some of the necessary adjustments have recently been thoughtfully considered by Mayberry *et al.* (2021) but there are many more unresolved challenges facing animal producers in Australia.

One of the core values of RA since its inception has been to bring research and industry participants together to identify the most pressing nutritional and environmental questions faced by the livestock industries and to recommend scientific solutions. Many innovative scientific developments have been unveiled at RA meetings in the past half-century, but few have been incorporated into profit-making ventures by commercial operators; R and D are not yet equal partners in Australia and this imbalance requires the attention of RA organisers. Resolution of wider problems such as those listed above will require substantially more funding for Research and Development (R&D) programs than is currently available. Fortunately, RA has been a template for guiding R&D and could, in the future, promote itself as a livestock-nutrition R&D (and extension) lobby group. An estimate of the total private and public funding of agricultural R&D in Australia is of the order of A\$3.3 billion (ABS 2020) but it is tough to quantify and explain the monetary benefits of this R&D. Nevertheless, the benefits are substantial and need to be widely publicised; for example, a recently developed index, known as the modified internal rate of return, puts this return at 16.4% per year (Rao *et al.* 2020).

Future organisers of RA will not be short of challenges! The planners of the 2023 meeting might consider the following suggestions:

- To capture the legacy of RA, make all of the RA papers presented before 2013 more accessible by uploading them to the RA website

- Investigate the advantages of having RA forge more formal linkages with other nutrition groups in Australia and overseas to create a National Animal Nutrition Association and, with this new status, seek funding to promote it as a vehicle for R&D and extension.
- Consider novel ways to enable research scientists and industry practitioners to interact, other than just by meeting at one venue every 2 years: (the Covid-19 pandemic has changed perceptions about the ways people can interact and has shown us that meetings may not always need to be held face-to-face).
- Continue to promote the existing ethos of RA by always challenging invited speakers to speculate and push the boundaries of animal nutrition and to discuss threats as well as opportunities. The multi-disciplinary, eco-system approach of Bill McClymont will become more relevant as critical global issues weigh even more heavily. Future RA organisers and their invited speakers must meet these challenges with innovative responses.
- Treat the 2021 meeting as another watershed in the history of RA and plan a strategy for meetings that anticipates critical animal nutrition problems ahead of the time when it will be too late to find the solutions.

Conflicts of interest

My academic degrees were gained in the Faculty of Rural Science at UNE. I have delivered numerous papers at RA meetings and been on the organising committees for 10 of the RA meetings. This background and my own biases will have influenced how this history of the RA symposium has been presented.

Acknowledgements

This, the third lecture in the Annison-Leng series, is dedicated to Frank Annison and Ron Leng who, with Bill McClymont, were my early career scientific mentors. I offer them my heart-felt gratitude as I'm sure will the many other scientists who have been similarly influenced and helped by them during their own careers. I thank David Farrell for sharing his memories of the 20 years when he championed RA, and for supplying two of the photographs reproduced in the text. I am grateful to Wayne Bryden, Roger Campbell, Mingan Choct, Tony Edwards, Roger Hegarty, Ray Johnson and Tim Walker for their recollections of relevant events and helpful discussions.

References

- Allan GL, Stone DAJ, Anderson AJ, Booth MA (2003) Carbohydrate metabolism in silver perch and barramundi. *Recent Advances in Animal Nutrition in Australia* **14**, 171–177.
- Annison EF (1987) 'Feeding standards for Australian livestock - pigs.' (Commonwealth Scientific and Industrial Research Organisation: Melbourne, Vic., Australia)
- ARC (1980) 'The Nutrient Requirements of Ruminant Livestock.' (Agricultural Research Council, Commonwealth Agricultural Bureaux: Slough, UK)
- Armstrong DG (1990) Introduction of the prize-winner – E. F. Annison – Sydney University, Australia. In 'Tagung des Verleihung des International Roche Research Prize for Animal Nutrition', 9 November 1990, Gruppe Ernährung, ETH Zurich, Switzerland. pp. 17. Volume Schriftenreihe aus dem Institut für Nutztierwissenschaften, Heft 4.

- Australian Bureau of Statistics (ABS) (2020) Value of Agricultural Commodities Produced, Australia. (ABS: Canberra, ACT, Australia) <https://www.abs.gov.au/statistics/industry/agriculture/value-agricultural-commodities-produced-australia/latest-release> [Verified April 2021]
- Beever DE (2003) Managing dairy cows for optimal performance. *Recent Advances in Animal Nutrition in Australia* **14**, 33–47.
- Beever DE, Hattan AJ, Cammell SB, Sutton JD (2001) Nutritional management of the high yielding cow into the future. *Recent Advances in Animal Nutrition in Australia* **13**, 1–8.
- Bell AW (2019) Standing on giant shoulders: a personal recollection of the lives and achievements of eminent animal scientists 1965–2015. *Animal Production Science* **59**, 1–34. doi:10.1071/AN18212
- Bell AW (2020) Animal science Down Under: a history of research, development and extension in support of Australia's livestock industries. *Animal Production Science* **60**, 193–231. doi:10.1071/AN19161
- Bell AW, Greenwood PL (2016) Prenatal origins of postnatal variation in growth, development and productivity of ruminants. *Animal Production Science* **56**, 1217–1232. doi:10.1071/AN15408
- Black JL (2014) Brief history and future of animal simulation models for science and application. *Animal Production Science* **54**, 1883–1895. doi:10.1071/AN14650
- Black J, Campbell R, Williams I, James K, Davies G (1986) Simulation of energy and amino acid utilisation in the pig. *Research and Development in Agriculture* **3**, 121–145.
- Black J, Gill M, Beever D, Thornley J, Oldham J (1987) Simulation of the metabolism of absorbed energy-yielding nutrients in young sheep. Efficiency of utilization of acetate. *The Journal of Nutrition* **117**, 105–115. doi:10.1093/jn/117.1.105
- Blair GJ (Ed.) (1977) 'Prospects for improving efficiency of phosphorus utilization. Reviews in Rural Science III'. Proceedings of a symposium held at the University of New England, August 1976, Armidale, NSW, Australia. (University of New England Publishing Unit: Armidale, NSW, Australia)
- Brake JT, Lenfestey BA, Plumstead PW (2003) Performance of broilers to 21 days of age produced by early lay broiler breeders is affected by cumulative broiler breeder pullet nutrition during rearing. *Recent Advances in Animal Nutrition in Australia* **14**, 81–85.
- Brooks PH, Beal JD, Niven S (2001) Liquid feeding of pigs: potential for reducing environmental impact and for improving productivity and food safety. *Recent Advances in Animal Nutrition in Australia* **13**, 49–63.
- Burkitt D (1969) Related disease-related cause. *Lancet* **294**, 1229–1231. doi:10.1016/S0140-6736(69)90757-0
- Campbell RG (1987) Energy and protein metabolism in the pig. In 'Manipulating Pig Production'. (Ed. JL Barnett) pp. 95–96. (Australian Pig Science Association: Melbourne, Vic., Australia)
- Campbell RG, Johnson RJ, King RH, Taverner MR (1990a) Effects of gender and genotype on the response of growing pigs to exogenous administration of porcine growth hormone. *Journal of Animal Science* **68**, 2674–2681. doi:10.2527/1990.6892674x
- Campbell RG, Johnson RJ, King RH, Taverner MR, Meisinger DJ (1990b) Interaction of dietary protein content and exogenous porcine growth hormone administration on protein and lipid accretion rates in growing pigs. *Journal of Animal Science* **68**, 3217–3225. doi:10.2527/1990.68103217x
- Chang A, Halley J, Silva M (2016) Can feeding the broiler breeder improve chick quality and offspring performance? *Animal Production Science* **56**, 1254–1262. doi:10.1071/AN15381
- Close WH (2003) Trace mineral nutrition of pigs revisited: meeting production and environmental objectives. *Recent Advances in Animal Nutrition in Australia* **14**, 133–142.
- Corbett JL, Freer M, Hennessy DW, Hodge RW, Kellaway RC, McMeniman NP, Nolan JV (1990) 'Feeding standards for Australian livestock: ruminants.' (Standing Committee on Agriculture, CSIRO Publishing: Melbourne, Vic., Australia)
- Cottle DJ (2013) The trials and tribulations of estimating the pasture intake of grazing animals. *Animal Production Science* **53**, 1209–1220. doi:10.1071/AN13164
- Cottle DJ, Nolan JV, Wiedemann SG (2011) Ruminant enteric methane mitigation: a review. *Animal Production Science* **51**, 491–514. doi:10.1071/AN10163
- Cuddeford D (1999) Recent advances in equine nutrition. *Recent Advances in Animal Nutrition in Australia* **12**, 99–105.
- D'Alfonso TH (1914) Factors affecting ileal digestible energy of corn in poultry diets. *Recent Advances in Animal Nutrition in Australia* **14**, 151–156.
- Davies DR, Smith M (2009) Aerobic deterioration of silage: causes, concerns and controls. *Recent Advances in Animal Nutrition in Australia* **17**, 57–63.
- de Beer M, Elfick D, Emmerson DA (2011) Is a feed conversion ratio of 1:1 a realistic and appropriate goal for broiler chickens in the next 10 years? *Recent Advances in Animal Nutrition in Australia* **18**, 9–13.
- de Souza-Vilela J, Andrew NR, Ruhnke I (2019) Insect protein in animal nutrition. *Animal Production Science* **59**, 2029–2036. doi:10.1071/AN19255
- DiGiacomo K, Akit H, Leury BJ (2019) Insects: a novel animal-feed protein source for the Australian market. *Animal Production Science* **59**, 2037–2045. doi:10.1071/AN19301
- Dougherty HC, Kebreab E, Evered M, Little BA, Ingham AB, Nolan JV, Hegarty RS, Pacheco D, McPhee MJ (2017) The AusBeef model for beef production: II. Sensitivity analysis. *The Journal of Agricultural Science* **155**, 1459–1474. doi:10.1017/S0021859617000430
- Douglas I, Gibson J, Streeten T (1991) 'Unusual losses in feedlot cattle at Texas, February 1991.' (Veterinary Services Branch and Pathology Branch, Queensland Department of Primary Industries: Brisbane, Qld, Australia)
- Dove H, Masters DG, Thompson AN (2016) New perspectives on the mineral nutrition of livestock grazing cereal and canola crops. *Animal Production Science* **56**, 1350–1360. doi:10.1071/AN15264
- Dunshea FR, McCauley I (2001) Immunization of pigs against gonadotrophin releasing factor (GnRF) prevents boar taint and affects boar growth and behaviour. *Recent Advances in Animal Nutrition in Australia* **13**, 65–71.
- Dunshea FR, Hung T-Y, Abit H, Rikard-Bell CV (2011) Feed additives and feed efficiency in the pork industry. *Recent Advances in Animal Nutrition – Australia* **18**, 105–114.
- Dunshea FR, D'Souza DN, Channon HA (2016) Metabolic modifiers as performance-enhancing technologies for livestock production. *Animal Frontiers* **6**, 6–14. doi:10.2527/af.2016-0038
- Edwards NS (2003) Nutrition of zoo animals. *Recent Advances in Animal Nutrition in Australia* **14**, 1–9.
- Edwards AC (2009) Significant breakthroughs in pig nutrition during the past 30 years and future challenges. *Recent Advances in Animal Nutrition – Australia* **17**, 113–117.
- Farrell DF (1999) Getting the most out of the feed we give our livestock. *Recent Advances in Animal Nutrition in Australia* **12**, 121–130.
- Farrell DJ (2014) 'The Academic Apple Tree.' (Australian eBook Publisher: Brisbane, Qld, Australia)
- Freer M, Christian KR (1983) Application of feeding standards to grazing ruminants. In 'Feed information and animal production'. (Eds GE Robards, RJ Packham) pp. 333–355. (Commonwealth Agricultural Bureaux: Farnham Royal, UK)
- Furness JB, Cottrell JJ (2017) Signalling from the gut lumen. *Animal Production Science* **57**, 2175–2187. doi:10.1071/AN17276
- Geier MS (2009) Feeding genes and the microbiota to benefit the host – a new paradigm for animal nutrition. *Recent Advances in Animal Nutrition – Australia* **17**, 65–72.

- Goddard ME, Bolormaa S, Savin K (2011) Selection for feed conversion efficiency in beef cattle. *Recent Advances in Animal Nutrition – Australia* **18**, 25–30.
- Greenwood PL, Bell AW (2003) Prenatal influences on growth and development of ruminants. *Recent Advances in Animal Nutrition in Australia* **14**, 57–73.
- Hadden G, Piotrowski C, Van Barneveld RJ (2013) Taking near infrared spectroscopy beyond feedstuff analysis to enhance animal production profitability. *Animal Production Science* **53**, 1179–1181. doi:10.1071/AN13264
- Harrison GA, Karnezos TP (2005) Can we improve the efficiency of nitrogen utilization in the lactating dairy cow? *Recent Advances in Animal Nutrition in Australia* **15**, 145–154.
- Herd RM, Pitchford WS (2011) Residual feed intake selection makes cattle leaner and more efficient. *Recent Advances in Animal Nutrition – Australia* **18**, 45–60.
- Hetland H (2007) Litter consumption in poultry—effect on nutrient digestion and gut health. *Recent Advances in Animal Nutrition in Australia* **16**, 21–26.
- Hocquette JF, Cassar-Malek I, Listrat A, Jurie C, Jailler R, Picard B (2001) Some recent advances in muscle biology and its regulation by nutrition: consequences for bovine meat quality. *Recent Advances in Animal Nutrition in Australia* **13**, 135–144.
- Hunter RA, Niethe GE (2009) Efficiency of feed utilisation and methane emission for various cattle breeding and finishing systems. *Recent Advances in Animal Nutrition – Australia* **17**, 75–79.
- Hunter MC, Smith RG, Schipanski ME, Atwood LW, Mortensen DA (2017) Agriculture in 2050: Recalibrating Targets for Sustainable Intensification. *Bioscience* **67**, 386–391. doi:10.1093/biosci/bix010
- Hynd PI, Weaver S, Edwards NM, Heberle ND, Bowling M (2016) Developmental programming: a new frontier for the poultry industry? *Animal Production Science* **56**, 1233–1238. doi:10.1071/AN15373
- Kahn LP, Johnson IR, Rowe JB, Hogan L, Boshoff J (2017) ASKBILL as a web-based program to enhance sheep well-being and productivity. *Animal Production Science* **57**, 2257–2262. doi:10.1071/AN17327
- Kamande GM, Spragg JC, Yoon I, Kujawa M (2005) Efficacy of dietary supplementation with yeast culture for grazing dairy cows and for calves. *Recent Advances in Animal Nutrition in Australia* **15**, 123–129.
- King RH (2009) Are co-products and algae cost-effective alternative nutrient sources for Australian livestock production? *Recent Advances in Animal Nutrition – Australia* **17**, 1–6.
- Klasing KC (1996) Immunomodulation in poultry. In 'Avian Immunology'. (Eds F Davison, T Morris) pp. 327–339. (Carfax Publishing Co.: Abingdon, UK)
- Klasing KC, Korver DR (1999) The role of diet in modulating the immune response of broilers: the example of PUFAs. *Recent Advances in Animal Nutrition in Australia* **12**, 1–6.
- Knowlton KF (2001) High grain diets for dairy cattle. *Recent Advances in Animal Nutrition in Australia* **13**, 19–28.
- Lean IJ (2013) Effects of retailer pressure on the efficiency of agricultural industries. *Animal Production Science* **53**, 1143–1148. doi:10.1071/AN13178
- Leng RA (1986) 'Drought feeding strategies: theory and practice.' (Peel Valley Printery: Tamworth, NSW, Australia)
- Leng RA (2014) Interactions between microbial consortia in biofilms: a paradigm shift in rumen microbial ecology and enteric methane mitigation. *Animal Production Science* **54**, 519–537. doi:10.1071/AN13381
- Leng RA (2017) Biofilm compartmentalisation of the rumen microbiome: modification of fermentation and degradation of dietary toxins. *Animal Production Science* **57**, 2188–2203. doi:10.1071/AN17382
- Leng RA, McWilliam JR (1974) 'Bloat. Reviews in Rural Science I.' (University of New England: Armidale, NSW Australia)
- Leng RA, Barker JSF, Adams DB, Hutchinson KJ (1985) 'Biotechnology and recombinant DNA technology in the animal production industries. Reviews in Rural Science VI.' (University of New England: Armidale, NSW Australia)
- Li L, Silveira CI, Nolan JV, Godwin IR, Leng RA, Hegarty RS (2013) Effect of added dietary nitrate and elemental sulfur on wool growth and methane emission of Merino lambs. *Animal Production Science* **53**, 1195–1201. doi:10.1071/AN13222
- Liu YG, Peng HH, Schwab CG (2013) Enhancing the productivity of dairy cows using amino acids. *Animal Production Science* **53**, 1156–1159. doi:10.1071/AN13203
- Lückstädt C, Mellor S (2011) The use of organic acids in animal nutrition, with special focus on dietary potassium formate under European and Austral-Asian conditions. *Recent Advances in Animal Nutrition – Australia* **18**, 123–134.
- Lynch GS, Koopman R (2019) Overcoming nature's paradox in skeletal muscle to optimise animal production. *Animal Production Science* **59**, 1957–1969. doi:10.1071/AN19361
- Lynch JJ, Hinch GN (2007) Feed recognition in sheep. *Recent Advances in Animal Nutrition in Australia* **16**, 37–43.
- Mann N (2013) Human evolution and diet: a modern conundrum of diet versus meat production, or is it? *Animal Production Science* **53**, 1135–1142. doi:10.1071/AN13197
- Masters DG (2018) Practical implications of mineral and vitamin imbalance in grazing sheep. *Animal Production Science* **58**, 1438–1450. doi:10.1071/AN17761
- Mayberry D, Hatcher S, Cowley F (2021) New skills, networks and challenges: the changing face of animal production science in Australia. *Animal Production Science* **61**, 201–207. doi:10.1071/AN20115
- Mayes RW, Lamb CS, Colgrove PM (1986) The use of dosed and herbage n-alkanes as markers for the determination of herbage intake. *Journal of Agricultural Science* **107**, 161–170.
- McClymont GL (1976) Animal production in a grain hungry world – or competition between man in a resource limited world. *South African Journal of Animal Science* **6**, 129–137.
- McClymont GL (1996) 'Rural Science: Philosophy and Application.' (Ed. JS Ryan) (School of Rural Science, University of New England: Armidale, NSW, Australia)
- McGarity JW, Hoult EH, So HB (Eds) (1984) 'The properties and utilization of cracking clay soils. Rural Science Reviews V.' (University of New England: Armidale, NSW, Australia)
- McGill J, Moss A, Swick R, Jackson D, Todd M (2019) The future protein decade: perspectives on global pressure to agriculture. *Animal Production Science* **59**, 1951–1956. doi:10.1071/AN19308
- Miettinen H, Li L (2009) The advantages of feeding ensiled high-moisture grain to livestock. *Recent Advances in Animal Nutrition – Australia* **17**, 29–34.
- Moshkin MP, Gerlinskaya LA, Zavjalov EL, Kolosova IE, Rogovin KA, Randall JA (2003) Stress and nutrition in the wild. *Recent Advances in Animal Nutrition – Australia* **14**, 11–22.
- Mottet A, de Haan C, Falcucci A, Tempio G, Opio C, Gerber P (2017) Livestock: on our plates or eating at our table? A new analysis of the feed/food debate. *Global Food Security* **14**, 1–8. doi:10.1016/j.gfs.2017.01.001
- Mullan BP, Moore KL, Payne HG, Trezona-Murray M, Pluske JR, Kim JC (2011) Feed efficiency in growing pigs – what's possible. *Recent Advances in Animal Nutrition – Australia* **18**, 9–13.
- NCN (2019) 'Nourishing Australia: a decadal plan for the science of nutrition.' (National Committee for Nutrition, Australian Academy of Science) Available at <https://www.science.org.au/files/userfiles/support/reports-and-plans/2019/2019-nutrition-decadal-plan.pdf> [Verified 1 June 2021]

- NFF (2018) 'Food, Fibre and Forestry Facts.' (National Farmers' Federation) Available at <https://nff.org.au/media-centre/farm-facts/> [Verified April 2021]
- Nielsen BD, Eckert SM, Robison CI, Mills J, Peters D, Pease A, Schott HC (2017) Omeprazole and its impact on mineral absorption in horses. *Animal Production Science* **57**, 2263–2269. doi:10.1071/AN17323
- Oddy VH, Dougherty HC, Oltjen JW (2019) Integration of energy and protein transactions in the body to build new tools for predicting performance and body composition of ruminants. *Animal Production Science* **59**, 1970–1979.
- OECD–FAO (2020) 'Agricultural Outlook 2019–2028.' (Organisation for Economic Co-operation and Development and Food and Agriculture Organisation of the United Nations: Paris, France)
- Ouwerkerk D, Maguire AJ, McMillen L, Klieve AV (2007) Why kangaroos do not produce methane. *Recent Advances in Animal Nutrition in Australia* **16**, 51–63.
- Payne CG, Gilchrist P, Pearson JA, Hemsley LA (1974) Involvement of biotin in the fatty liver and kidney syndrome of broilers. *British Poultry Science* **15**, 489–498. doi:10.1080/00071667408416137
- Perdok HB, Leng RA (1984) 'Bovine Bonkers.' (Audio Visual Centre, University of New England, Armidale, NSW, Australia) [Video tape]
- Péron A, Partridge GG (2009) Contribution of exogenous enzymes to the preservation of limited feed resources. *Recent Advances in Animal Nutrition – Australia* **17**, 9–17.
- Pluske JR, Miller DW, Sterndale SO, Turpin DL (2019) Associations between gastrointestinal-tract function and the stress response after weaning in pigs. *Animal Production Science* **59**, 2015–2022. doi:10.1071/AN19279
- Preston TR, Leng RA (1987) 'Matching ruminant production systems with available resources in the tropics and sub-tropics.' (Penambul Books: Armidale, NSW, Australia)
- Preston TR, Willis MB (1970) 'Intensive Beef Production.' (Pergamon Press: Oxford, UK)
- Pryor WJ (1980) Introduction of nationally uniform feeding standards for Australian livestock. *Proceedings of the Australian Society of Animal Production* **13**, 18–19.
- Rao X, Hurley TM, Pardey PG (2020) Recalibrating the reported returns to agricultural R&D: what if we all heeded Griliches? *The Australian Journal of Agricultural and Resource Economics* **64**, 977–1001. doi:10.1111/1467-8489.12388
- Raubenheimer D, Simpson SJ (2007) Geometric analysis: from nutritional ecology to livestock production. *Recent Advances in Animal Nutrition in Australia* **16**, 51–63.
- Rojas OJ, Stein HH (2016) Use of feed technology to improve the nutritional value of feed ingredients. *Animal Production Science* **56**, 1312–1316. doi:10.1071/AN15354
- Rowe JB (2003) Nutritional management of the Australian sheep flock. *Recent Advances in Animal Nutrition in Australia* **14**, 23–31.
- Rural Bank (2021) 'Australian agricultural trade: Australian agricultural exports 2019/20.' Available at https://www.ruralbank.com.au/siteassets/_documents/publications/trade/trade-report-2020.pdf [Verified 15 March 2021]
- Russell JB (1999) Excessive grain feeding; acid-resistant bacteria and their impact on cattle. *Recent Advances in Animal Nutrition in Australia* **12**, 73–79.
- Ryan JS (2007) 'McClymont's Vision: The Challenge Remains: Rural Science 50th Anniversary Conference 2006.' (University of New England: Armidale, NSW, Australia)
- Sibbald IR (1976) A bioassay for true metabolizable energy in feedingstuffs. *Poultry Science* **55**, 303–308. doi:10.3382/ps.0550303
- Sklan D (2003) Early nutrition and its effect on lifelong productivity in poultry. *Recent Advances in Animal Nutrition in Australia* **14**, 75–79.
- Sunstrom F, Owen E (1984) 'Straw and other fibrous byproducts as feed.' (Elsevier: Amsterdam, The Netherlands)
- Sutherland TM, McWilliam JR, Leng RA (Eds) (1976) From plant to animal protein. Reviews in Rural Science II. Proceedings of a symposium held at the University of New England, Armidale, NSW, Australia, August 1975. (University of New England Publishing Unit)
- Swick R (2011) Global feed supply and demand. *Recent Advances in Animal Nutrition – Australia* **18**, 1–6.
- Tao RC, Asplund JM (1975) Effect of energy sources on plasma insulin and nitrogen metabolism in sheep totally nourished by infusions. *Journal of Animal Science* **41**, 1653–1659. doi:10.2527/jas1975.4161653x
- Thomson M, Rowe JB (Eds) (2019) Concept to impact: the story of the Sheep CRC 2001–2019. Sheep CRC Ltd.
- Trottier NL, Tedeschi LO (2019) Dietary nitrogen utilisation and prediction of amino acid requirements in equids. *Animal Production Science* **59**, 2057–2068. doi:10.1071/AN19304
- van Barneveld RJ, Nuttall J, Flinn PC, Osborne B (1999) NIR reflectance measurement of the digestible energy content of cereals for growing pigs. *Journal of Near Infrared Spectroscopy* **7**, 1–7. doi:10.1255/jnirs.228
- Vandepuer ME, van Barneveld RJ (2005) The use of terrestrial nutrition principles and techniques to advance Australian abalone aquaculture. *Recent Advances in Animal Nutrition in Australia* **15**, 215–220.
- Walk CL (2016) The influence of calcium on phytase efficacy in non-ruminant animals. *Animal Production Science* **56**, 1345–1349. doi:10.1071/AN15341
- Webster AJF, Dewhurst RJ, Waters CJ (1988) Alternative approaches to the characterization of feedstuffs for ruminants. In 'Recent Advances in Animal Nutrition'. (Eds W Haresign, DJA Cole) (Butterworths: London, UK)
- Williams BA, Gidley MJ (2007) Fermentation and porcine gut health. *Recent Advances in Animal Nutrition in Australia* **16**, 161–167.
- Wiseman J (2013) Influence of processing on the digestibility of amino acids and starch in cereals and legumes in non-ruminants. *Animal Production Science* **53**, 1160–1166. doi:10.1071/AN13254
- Wodzicka-Tomaszewska M, Edey TN, Lynch JJ (Eds) (1980) 'Behaviour in relation to reproduction, management and welfare of farm animals: reviews in rural science IV.' (University of New England: Armidale, NSW, Australia)
- Zhang S, Trottier NL (2019) Dietary protein reduction improves the energetic and amino acid efficiency in lactating sows. *Animal Production Science* **59**, 1980–1990. doi:10.1071/AN19309

Handling editor: Frank Dunshea