will provide managers with the information to reduce the variability in performance across animals and land, and reduce their impact on the environment. With these data available in the future, there is a huge need for system integrators who can pull it together, interpret and turn it into practical recommendations. Farmers will require all IT providers to collaborate and work together so the information can be provided on a common IT platform, removing current problems and constraints in this area.

I am imagining a world where both farmers and other value chain partners will have realised the value of R&D investment, and New Zealand will be investing 2-3x more in R&D, with new innovations rolling out to support agriculture. Investment in collective marketing and brand development will have not just doubled over the next 20 years, but will have grown by a factor of at least 4-fold from today's levels. While there will be a cost in getting this going the long-term return will be large and this will be the only way farmers will ever break out of supplying commodities. We cannot sit and wait for Government to drive this. Farmers and industry bodies need to stand up and develop a clear and compelling vision for government to invest in.

Tourism is a sector that agriculture must work far closer with as both industries need to leverage off each other to realise their potential, and make the New Zealand experience truly enduring. I recently had an international chef (whom I met on the top of a mountain) tell me that during her 3 week stay in New Zealand, she had experienced the freshest and tastiest food ingredients that she ever had in all her travels around the world. How do we allow global customers bitten by their Kiwi experience to continue directly buying premium food ingredients, daily, when they return home? I would love to see the "My Food Basket" concept expanded globally to a "Kiwi Food Basket". An on-going connection with our country via our food will encourage visitors to return and recommend the experience to their friends.

Over the next 25 years New Zealand farming businesses will need to develop greater resilience at all levels to live and thrive in a world experiencing global warming. Climate change will shape all our thinking over the next few decades. Most farmers in the world are well prepared for climate change, but in New Zealand we seem slow to recognise and accept what is impacting on us already. Other things coming towards us at full speed that we need to be proactive about and not just react to when the issue blows up include:

a. Carbon emissions with agriculture potentially being included in an Emissions Trading Scheme
b. Tighter animal welfare standards with some current practices not being acceptable
c. Unintended results from micro-testing of our food products.

I am sure over the next 20 years the agricultural industry would have moved away from entrenched positions it holds today, and will have accepted that change is necessary and must be embraced. I hope that our industry and marketing organisations will be working far more seamlessly together and that an umbrella grouping has set a farmer-driven but consumer-lead vision for our Agri-food Industry. This same group may well be the spokesperson for the media on general agricultural issues projecting a consistent and balanced view of agriculture. This would help make farmers and others in the industry feel less like victims, and hopefully, move farmer mind-sets more to accepting challenges and being proactive in trying to find solutions.

We all intuitively know that our future as a pastoral industry will be defined over the next 10-20 years. My vision is that the pastoral industry will be recognised as being a customer focused, and highly profitable, with an ever-decreasing environmental footprint and an ever-increasing investment into branding, research, innovation and staff training, attracting the best and brightest into our sector and rewarding them well.

I honestly believe this vision can be realised, but alignment and unity right across the value chain from the farmer to the market will be needed. Firstly, agree on a common vision and purpose, and then commitment and capital from all players will follow. Structure follows strategy and agreement on a combined strategy or vision before jumping into discussing operating structures. Nothing will ever happen without first collaborating across our pastoral industry. This can be scary because it potentially involves change and often means giving up something.

But the prize in front of us is huge. Our industry can be recognised as being the restaurant for the 50 million high net worth foodies of the world. If we do not grab this opportunity, then other countries will claim the moral high ground and the market positioning it enables. In my mind, retaining the status quo is not an option and is a far riskier than embracing the vision I am proposing. This is the industry I am wanting to be part of over the next 20 years of my career. Those just starting their careers are fortunate to have joined this fantastic industry at a critical time when some key strategic decisions need to be made. I encourage you to step up and ask lots of questions and challenge the status quo, providing leadership not just observers in this industry, as it is your future that is at stake more so than for the existing players.

Finally, I would like to sincerely thank the NZGA Executive Committee for presenting me with this award. I would also like to acknowledge and honour those award winners who have gone before me, including last year's winner, the late Colin Holmes.

NZGA PRESIDENT'S ADDRESS 2016
Systems research: the need for a change of thinking

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Farm systems research has a long history of success in New Zealand. Recent reviews have highlighted the progress made through the traditional and pragmatic approaches that have been used (Clark 2013; Stevens *et al*. 2016). However, as the world and technologies change ever more rapidly around us, is it time to change from the pragmatic problem solving approach to one of deeper understanding?

Professor Shaun Hendy defined the need for new thinking at the launch of the recently formed Te Punaha Matatini, the Centre of Research Excellence for Complex Systems and Networks. He said "by understanding the networks that underlie each of these complex systems we will get insights into how to influence them and how to develop better strategies for managing them". The power of systems research provides the opportunity for New Zealand to define its own path and make its own decisions. These opportunities come through understanding how systems will respond, or how they can be reconfigured, to capture benefits specifically to meet our needs, rather than the needs of others.

A science critic and past research director suggested in a recent article that a focus on farm systems research (or application) was in the realm of primary industry farm advisory professionals, not the science effort (Allison 2016). He based his view on the notion that farmers will take up and incorporate technologies into their farming systems if and when the technology offers an improvement in value to the farmer. This belies the common belief that farm systems research is about demonstrating the value of technologies at a farmlet scale. Unfortunately this belief is flawed.

The argument presented is that farm systems research is about demonstrating the fit of technology into current systems. While this may be one option or outcome, the more fundamental reason for farming systems research is to understand what drives the system and alters the value of the system, and then begin to develop new systems that may return greater value. The concept of putting technologies into a current system has a tendency to rely on incremental gain. While this has some merit, it locks us into the current paradigm, rather than imagining new futures.

The key to understanding systems research is to understand the holistic nature of the approach. Traditional research is reductionist in approach (catabolic), breaking the system into its constituent parts and examining these in isolation, in the attempt to understand the base function of each component. This requires tight control to reduce internal variables and external influences. Systems research embraces this variation and examines the system in reference to the variables around the system that drive its performance. It is about synthesis (metabolism) of processes into functioning systems.

Systems science uses a holistic approach to study the system as a whole to understand the outcomes and properties of the system rather than the component parts. To demonstrate the nature of the difference between reductionist and holistic approaches we can use the bicycle as an analogy.

Do you own a bicycle? Most of the population of the world has ridden a bicycle. Is yours an old faithful for riding quietly to work or a state of the art road bike or mountain bike? Do you ride it for pleasure, necessity, exercise, competition or thrills? How much did your bicycle cost, and how much technology is embodied in your bicycle?

When disassembled into its component parts a reductionist approach would examine the gears, chains, levers, wheels etc. Each component may be high or low tech, made of steel or carbon fibre, precision made or roughly hewn.

When assembled the bicycle can do something that any one of the parts cannot. It exhibits emergent properties – it evolves into a mode of transport. That outcome cannot be readily seen from examining the components in isolation. Even when assembled, it is not finished. It needs a rider to complete a function – have meaning or purpose. Then we have an operating system.

The system has a boundary that sits around the bicycle and the rider. The system sits within other systems, the road network or the track, for example, and so exhibits nesting. The system interacts with its surroundings; the friction of the road, the drag of the wind, and the motorists around it. And so it interprets its environment and learns from feedback. The gears need to change, the effort of the rider has to increase, the brakes need to be applied, the car dodged. The system evolves. The penny farthing was replaced by the chain-driven cycle, the 10-speed with the 18-speed, and the mountain bike

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emerged as a subspecies.

The needs of the system define the application of the needs for the components. If I ride to work I choose a different option than if I careen madly downhill. The technology is different, the complexity of components increases, and the needs are much different. Sometimes the need is transport to work, sometimes the requirement for exercise, or the emotional thrill of speed and danger. And so the systems, though all based on a bicycle and a rider, produce different outcomes or products, and so meet different needs. There is an underlying set of needs, there is an underlying set of first principles about riding a bike, and there is an underlying set of base components. But in combining those three elements the outcomes from the 'bicycle system' are diverse. This diversity furthers emergent properties and evolution.

If we were to examine a single bicycle/rider combination what would we learn? If I were to examine myself I would find different purposes, different technical needs, and different investment and training over a broad temporal horizon. In my youth I used a bicycle for exercise, to pursue the love of my life, to get to lectures. The bicycle was fast and light, and as expensive as I could afford. My current bicycle was bought on TradeMe for $20, is heavy and relatively unused.

My son's bicycles have become more and more expensive, with greater investment in technology culminating in an $8000 purchase. The need for speed outgrew the skill to go faster and so skill was replaced by technology. These bicycles require full face helmets and body armour, disc brakes and titanium frames. His needs are for exercise and gratification of the senses – the thrills of riding downhill fast. And so who is right? Which technology should the next cyclist choose or invest in, based on our case studies?

The role of systems science is to examine the 'system' and understand the drivers of the system. These occur both inside and outside the system. The examination of the system does not then prescribe which is 'best', but provides an understanding of what makes them different, as is the case in the bicycle analogy. This understanding can direct how the attendant system properties create the outcomes and outputs from the system, the meaning (or purpose) for the system and how the system might evolve in response to different needs, stimuli or pressures.

What we might have viewed as a simple system of a bicycle and its rider becomes complex as we add need and technology.

And so sits systems research as a distinctly different entity to traditional science. Do the components of the research always need to be holistic? The answer is no. The vision and initial testing of ideas may sit at the systems level. That helps imagine what it might become and to determine the potential value, but the subsequent research programme may have elements of both holistic and reductionist elements. This places the two approaches alongside one another. By using a holistic approach the needs of the end user are placed much more at the centre of the development of future solutions or technologies. The old model of scientists knowing what is best and presenting the science as a 'fait accompli' is a thing of the past. The holistic approach sits at the centre of co-innovation and better-by-design processes.

An example of the power of both approaches comes from the 'Lucerne for Lambs Sustainable Farming Fund' project. In brief, the project aimed to increase the use of spring grazing of lucerne in Central Otago. It was hypothesised that using lucerne as a grazing option in spring would increase the profitability and resilience of Central Otago farmers (Stevens *et al*. 2012).

The question may be asked, why choose this environment where lucerne was already known? This belies the belief that farmers take up new technologies as required. Farmers in the region knew the product, but put it to different use, fulfilling a different need. This created a specific set of traditional expectations and biases. These became impediments to introducing a new concept that would change the farm system.

Examining the current set of beliefs became key to developing a research programme. The research needed to provide answers in a way that changed expectations and introduced a change in the farming system (Casey *et al*. 2015).

Matching the new understandings of lucerne grazing management, developed through reductionist science, to the needs of the whole farm system provided the mechanisms to demonstrate potential profitability and resilience (Stevens & Casey 2014). Without the fundamental science principles then the project could not have worked. Without the systems view of understanding the drivers of the farm system then the fundamental principles would not have been adopted. This demonstrates the power of combining the two approaches.

Interestingly, the farm systems that have emerged to capture this benefit are wide and varied. They range from the integration of lucerne into large scale properties to empower the productivity of native hill country, through to intensive finishing systems (Stevens *et al*. 2012). So the lessons of the first principles of science are incorporated into a range of system types based of the needs and skills of the participants, all developed from an understanding of the resources that each farmer had available. Answering the underlying questions that affected the system provided the opportunity for adaptation (Casey *et al.* 2015).

Systems science requires a different range of methodologies from reductionist science to ensure its

success. An example comes from an emerging branch of chemistry, computational chemistry. This approach has been developed out of quantum mechanics and has been supported by the availability of the power of supercomputers. It uses theoretical knowledge of the behaviour of electrons to understand how atoms and molecules interact. The equations involved must be solved using approximations, due to some aspects of electron behaviour being infinitely complex. Solving these equations is still not a trivial effort. These approaches are metabolic, building a view of processes from first principles. New insights are being gained into, for example, the functioning of catalysts used in the Haber-Bosch process (used as the first step to make nitrogenous fertilisers).

Systems science can then be seen being used at completely different ends of farming, and at completely different scales, from the smallest atom to the largest farm.

The methodologies used in this discipline are similar to those that may be used in farm systems research. The use of model systems is a starting point to examine potential pathways, and the outcomes can be subjected to analytical techniques such as Bayesian network analysis and Monte Carlo simulation approaches, to determine variability and error terms. These techniques are common to both computation chemistry and social science.

This provides a classic example of a systems approach to science. Known or near known first principles are used and combined through modelling to generate new understandings that are difficult to examine through experimentation. While this research is in its infancy, the potential outcomes from the understanding it will provide are considerable, and help augment traditional approaches to chemistry.

So how do we reconcile the research into nano-particle behaviours with farming systems research? Several similarities come to mind. The first is the research techniques that can be used. Another is the creation of surface maps of hydrogen atom energy gradients that provides insight into the pathways that hydrogen atoms may use to move around a system. If we take this as analogous of, for example, the movement of finance through a farming community then we could better define the relative probabilities of investment in one sector or enterprise over another.

The 'Rural Futures Multi-agent Simulation (RF MAS)' project modelled exactly this type of process when examining the rise of dairy farming in the southern region of New Zealand over 20 years (Kaye-Blake *et al*. 2014). RF MAS is currently the only fully integrated, spatial, simulation model of agriculture for New Zealand regions. The value of this work was not in the retrospective calibration of the model, but in the creation of the model itself. The model required specific inputs about farming practices and profitability, rural social influences and financial liabilities, as well as land use capability. That those variables were then able to be assigned values that predicted land use change provides tools to examine the impacts of a range of changes, such as relative profitability of sectors, government policy, and social pressures on farming.

So, do we continue to apply a pragmatic problem solving approach to researching the questions one at a time attempting to fit new technology to an old system? Do we change focus and take a lesson from the bicycle? The techniques of systems science can span the breadth and depth of the systems that we use, from the hydrogen atom to whole farm systems and beyond. A holistic approach to examining the underlying first principles of farming systems will provide new insights. Then research programmes will have new understanding of the real power of transformational change. New Zealand Inc., will be better placed to take control of our future exactly as envisioned by Professor Shaun Hendy at the inauguration of 'The Meeting Place of Many Faces', our 'Centre for Research Excellence in Complex Systems and Networks'.

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