Article

Research and innovation

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…Research is not a slot machine wherein funding generates results in nice tidy slices in three- to five-year time intervals.
Julia Lane[§], 2014

This article was prompted by the keynote address entitled 'Highlights and lowlights of a science career in AgResearch' given by Professor Susanne Rasmussen at the New Zealand Association for Women in the Sciences Conference, 2014.

Introduction

Good scientific research is a *condicio sine qua non* for progress. Nobody has shown that advances can be made without some sort of research; funding the research process and allowing scientists with a track record to lead their research for public good would seem the best way to achieve what is desired. Despite the logic, science continues to struggle in New Zealand. The quantity of funding available and the funding allocation model are part of the problem, but so are the managerialism, competition and the erosion of independence that the model has created. The result is a science system under considerable stress, increasing public mistrust of results, and a decrease in engagement in science subjects at school. In New Zealand, both current and future capability is evaporating. For agriculture, which continues to form the basis of the export economy, the implications are dire. This paper considers the trends and identifies action for the future.

Research and innovation – from first principles

From first principles it is not difficult to conceive how to create and sustain a world-class, cost-effective, research 'service', which could be a function fit for both national and industry goals. In the last two decades, through different governments, the presumption has been that this could be achieved by adopting a business model, notably in the Crown research institutes (CRIs) and increasingly in universities. Despite this focus, what has arisen is almost the antithesis – an inefficient, not cost-effective, and not-altogether trusted 'bureaucracy'. Evidence of this lies in the increasing level of monitoring, scrutiny and intervention

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by boards, industry and government ministries alike. Further evidence is provided by the constant re-organisation and restructuring, even though past re-organisation attempts have clearly failed to deliver the cost-effective, efficient research service that was the goal. We argue here that we have passed the tipping point: over-control, intervention and interference have enabled costly infrastructures and poor organisational behaviours, which are substantially counter-productive. An important distinction to resolve in planning for a better research and innovation future is whether the fundamental problem lies with *scientists*, as is evidently so widely presumed, or with how ineffectively science is *managed*.

The recipe for success is simple. Firstly, set up research facilities within the given budget prospects. Secondly, attract and appoint the world's best research scientists and innovators, locally or from overseas. These are not difficult to distinguish, as in science the independent evidence of performance is clearly recorded and widely available. Thirdly, recognise success, reward and retain key staff. Given the cost of building infrastructure around them, it pays dividends to retain them; if they are the world's best, or the best you managed to attract, there can be no presumption they are readily replaceable. Note that performance in this profession is easily re-assessed and so retention carries little risk. Fourthly, having appointed the best professionals, empower them to innovate and make progress within the bigger-picture direction and strategy for the institution and country.

Finally, the whole premise of a best business model doctrine, cost-effectiveness, is best served by appointing only those non-science roles that are essential for supporting and administering the organisation's key purpose of delivering science and innovation. The greater the level of external direction, the lower this infrastructure cost should become.

Of note is that income ('funding') is based almost entirely on the reputation and direct involvement of the existing key science staff. These staff are heavily relied upon to acquire the organisational funding and support by contributing to the development of strategy and policy through their membership on industry and government review panels. They then have to show the relevance of their work to the agreed focus and direction, as well as taking the risks of innovation in new areas. Repeated 'customer' surveys by CRIs report the greatest 'customer' satisfaction is when dealing directly with these key (active) science staff who are recognised widely as being self-motivating, deeply committed, eager to engage; they also have a serious concern for what and who they serve.

There is nothing about this simple ideal that is inconsistent with the notion of running a cost-effective, successful, business, if that is how it is to be perceived, but neither the ideal, nor cost-effective business, has arisen (Edmeades 2004).

The problem in agriculture

The National Government has a strong commitment to innovation articulated through the Business Growth Agenda.[1] The goal of increasing the ratio of exports to GDP to 40% by 2025 relies heavily on the primary sector; initial suggestions were doubling its value by 2025. Future Direction 2014 [2] emphasised the Government's commitment: 'innovation is essential to ongoing productivity growth and job creation. Innovation is also central to the overall target of increasing exports to 40% of GDP by 2025.' The focus, however, is on business: 'It (innovation) enables firms to produce higher-value products and services, and produce them more efficiently, thus creating points for commercial success'.

Increases in overall expenditure on R&D have occurred, but overall funding in New Zealand is still only marginally above the OECD average[3], and considerably behind iconic innovative economies such as Israel, Denmark and Finland; of note is that China now invests in R&D at the EU28 rate (almost 2% of GDP in contrast to NZ at 1.26%) and Korea's investment has escalated in recent years to 4.36% GDP[4].

New Zealand is suffering, having been neither a high investor in the past, nor ramping up investment now, but has climbed since 2005 (1.13% of GDP) at the same time as the economy has been growing. The Government reports that a major driver of the increase in R&D has been research expenditure by private businesses: funding increased by 17% between 2010 and 2012. Part of this was stimulated through the Primary Growth Partnership[5], by which the Government aims to boost primary sector productivity.

The difficulty with private business-funded research as a means to increase research on national goals is that it is inevitably focussed on topical interests, of immediate financial implication for the funders. The risk is that any research findings lack independence (and so trust is compromised in the mind of the public). A further risk is in diverting attention from wider, or longer-term, national strategies and concerns. Climate change research, biosecurity, and environmental impacts are common examples of research direction that is traditionally in the public good funding basket; private funding is uncommon.

Research based on the directions of private businesses is also of necessity short-term in order to achieve milestones and outputs for the funders. Models and surveys (which can give results more quickly than fundamental biological research) are being used as a proxy for science, obscuring the realities of progress in scientific understanding. Recent initiatives, aimed at drawing in industry funding contributions, have, instead of enhancing the existing research base, opened the door for newcomers, and so new infrastructures. When the funding expires, this leaves ever more competition in the public research marketplace for a sinking lid fund. In 2009, AgResearch's then chief executive Dr Andrew West estimated there had been a 70% decrease (in real terms) in government support for R&D in the field in the past 25 years.

The decline in agricultural research has been global, despite multiple analyses showing beneficial rates of economic return on dollars invested in R&D (e.g. Alston 2010). Competing demands for S&T (science and technology) investment, plus increasing complexity in agricultural S&T systems, have been blamed for the deterioration in science globally. Complexity has required new organisational structures (and hence reorganisations), increased participation by the higher education and private sectors, and diversification of funding sources (Beintema & Stads 2008).

1 See http://www.mbie.govt.nz/what-we-do/business-growth-agenda

2 See http://www.mbie.govt.nz/pdf-library/what-we-do/business-growth-agenda/bga-reports/future-direction-2014.pdf

3 See http://www.oecd.org/newzealand/sti-outlook-2012-new-zealand.pdf

4 See http://www.oecd.org/sti/msti.htm

5 See http://www.mpi.govt.nz/agriculture/funding-programmes/primary-growth-partnership.aspx

While the supply of money for research and innovation will at all times affect the overall 'scale' of the operation, and while any long-term decline in real terms in funding creates its own systematic concerns, none of that deflects from the significance of seeking how to get the most valuable research for whatever funding is available. The nub of the problem is the near total loss of 'trust' in *existing* infrastructures of science and scientists, by government and industry agencies.

The most explicitly stated concern is that scientists left in any way to their own devices would over-indulge in their personal interests and perspectives, and not attend to a more 'relevant' direction. Given that scientists must bid for their funds from the same bodies, this is scarcely a rational concern, but, more significantly, it indicates a fundamental error in logic. Few days pass when the media fail to report the many new challenges to society and its economic and welfare sustainability. Government, industry and the public understandably demand immediate answers. However, to have the answers to what is topical 'now', someone must have been indulging themselves in getting answers in the past. If we accept we have a case for research and innovation at all, a proportion of that effort has to be looking forward. Of note is that a key attribute of successful businesses such as Microsoft, Apple and Virgin is that they indulge the focus of innovative individuals because that was their genesis.

The capacity for foreseeing what will later become highly relevant is not difficult to spot in an individual, as it is evident from their publication and engagement record. Politicians or industry leaders are unlikely to be any better at foresight than scientists, yet they are directing and terminating scientific research. In fact, they may well be worse at foresight. For example, early this century all research on irrigation for dairy pastures was stopped, and staff lost, on the premise that no-one in New Zealand would ever irrigate pastures for ruminant production…

With trust evaporating on administratively trivial problems, the door is opened to management-driven control and accountability. Business-minded individuals may think 'rightly so' but this suggests a deep confusion between 'management' and 'leadership' (which is what distinguishes the three business examples mentioned earlier). As a result of management, research and innovation facilities endure a continuing level of interference that few businesses would tolerate or survive.

Management and leadership

Developed as a concept during the late 1800s, scientific management (also termed Taylorism after the concept developer) of employees was based on finding their skills and then empowering them with appropriate resources and a collegial environment to do their creative best towards the goals of the employer. Dr Craig Venter, Venter Institute, USA, explains his remarkable achievements in sequencing human DNA as picking the right people with whom to work. He hires 'the best people in the world and gives them the latitude to do what they are great at'. Although he sets the driving goals and overall agenda, the execution of goals is by the individuals in charge of their own programmes, or is a team decision. He chooses employees who are creative, flexible, who like to be challenged every day and who are self-motivating (Venter 2014).

Similarly, considerable success was obtained in the UK and Germany basing 'core' research centres around distinguished science individuals such as May, Krebs and Planck. The ideal of the Max Planck Institutes in Germany was the original model for the Marsden Fund (see Box 1).

In some contrast, the CRI model has a top-down approach in which science is prescribed by managers who are often not qualified in the area required to know what research should be done. The highest science grade has less authority than the bottom managerial grade and this leads to (and epitomises) lack of respect for scientists (and their profession) and reduced recognition of scientific delivery.

The effect for scientists in New Zealand has been that management has increased, internal reporting has escalated, and research has changed in nature from the pursuit of excellence and knowledge, to meeting the 'letter' of lengthy prescribed milestones in fewer real research and innovation contracts, and more 'jobbing' ones. The worth of a staff member is assessed on their current capacity to attract yet more new funding; this has very little to do with track record. Because those assessing performance, internally, are often not experienced scientists with a high-calibre track record, capacity to identify who best to conduct the work, even based on their past performance, evaporates (Stern 2007). Interest by managers in the research often ends almost as soon as the contract revenue has been acquired because the goal for the manager is more money. This means some excellent developments – which are the very benefits of conducting research – can fail to be followed up, as any new topical external funding interests will take precedence over substantiating progress made in a previous initiative.

Forty per cent of scientists report that they now spend more than 30% of their time on paperwork, bidding, justifying and accounting (Sommer 2010). Paperwork is antithetical to meaningful progress, and yet being able to make progress is the top motivator of performance (Amabile & Kramer 2010). 'Enabling progress' is within the control of leaders and managers; bureaucratic management systems lead to low motivation and morale (Amabile & Kramer 2010).

Goodall and Bäker (2004) have shown that top research universities and institutions are led by top researchers, top hospitals are led by top physicians and top basketball, football and formula one teams have coaches who were top players and drivers (see Box 2). Although it has been assumed that because experts and professionals are driven largely by intrinsic motivation, extrinsic management and leadership are less im-

Box 1: Origins of the Marsden Fund

Sir Ian Axford, then Chairman of the Board for the Foundation of Research, Science and Technology and later inaugural Chair of the Marsden Fund Committee, 'had been very impressed with the Max Planck Society in Germany, which is dedicated to the advancement of knowledge (science) – when I asked its President what he wanted done in our Institute he said simply that he did not care as long as it was good – and it worked.'

http://assets.royalsociety.org.nz/media/marsden-fund-update-033.pdf, p. 24.

Box 2: Expert leaders positively influence organisations (Goodall & Bäker 2014)

Decisions and actions

1. Expert leaders implement more profitable organisational strategies than manager leaders
2. Expert leaders create a more appropriate work environment for core workers than manager leaders
3. Expert leaders hire better employees than manager leaders

Expertise as a signal

4. Because expert leaders are more credible than manager leaders, they are more willingly followed by core workers
5. Expert leaders attract better potential employees than manager leaders
6. Expert leaders appear in a more positive light for external stakeholders than manager leaders

portant in knowledge-intensive organisations, this assumption is wrong. In fact, experts and professionals need to be led by other experts and professionals who have a 'deep understanding of, and high ability in, the core-business of their organisation'. It is important to note, however, that expert knowledge is not a proxy for management skills and leadership experience: both are necessary prerequisites (Goodall & Bäker 2014).

For science, leading a team requires expert knowledge, a track record in scientific publication, enthusiasm and passion, innovative ideas, listening to the team, respect, trust and honesty, emphasising strengths and rewarding and celebrating achievements. In contrast, managing a team seems to be predicated on 'soundbite' knowledge, personal career goals, reporting rather than publishing, copying ideas from other places, listening to senior management, micromanagement, emphasising weaknesses and punishing rather than rewarding. This was the subject of Professor Rasmussen's keynote address to the 2014 New Zealand Association Women in the Sciences Conference.The move into 'managerialism' has been years in the making, and articles have been published expressing dissatisfaction (e.g. Edmeades 2004, Sommer 2010) and explaining better ways of managing research (e.g. Edmeades 2004; Rowarth 2009, 2010; Rowarth & Goldson 2009; Rowarth & Parsons 2011). In combination with underfunding, managerialism has had a significant detrimental effect on not only existing staff job satisfaction (essential for creativity and attracting/retaining world-class science staff), but worse so on future prospects: two thirds of CRI scientists would not now recommend science as a career to the next generation (Sommer 2010).

Harvard Business School research (Mankins 2014a) has shown that people who work for inspiring leaders are more committed, satisfied and productive than those that don't; they are also less likely to leave their jobs. Employees' engagement is directly related to a leader's ability to inspire people, not to a manager's determination to assign tasks.

While it is expressed widely that any inadequacy in research delivery lies at the feet of research scientists (who are subject to repeated assessment), very little attempt has ever been made (internally or nationally), to measure and so seek objective evidence for the efficacy and outcome of the near endless rounds of restructuring that follow each and every shifting between CRIs of the CEO, or of the increasing intervention of their boards.

The problem for science is that, while the role of management in adding any value to the ability to do the research is unmeasured and unclear, managers do absorb considerable resources. Estimates (Mankins 2014b) are 2 FTEs for one basic management position and 3.2 FTEs extra per senior executive. Highly remunerated 'business developers' are not doing the actual business of the company, they are managing the performance of the people who are the revenue generators. Successive restructurings in CRIs and universities have brought in each instance a new layer, or even a cross-cutting extra 'matrix', of management positions (e.g. Woodford 2014). For example, in AgResearch between 2011 and 2014 there was a 14% decrease in science staff and a 25% increase in management and support positions (AgResearch 2011, 2014).

Reorganisations

Restructuring and reorganisation are clear evidence of a presumption that there is something about a current establishment or business that is awry. Strangely it occurs in New Zealand even when CEOs of CRIs move between establishments, which raises the paradox that, ***if*** there was something mismanaged about organisation 'x', why was this vision allowed to pass now to organisation 'y'? Restructuring, again, needs testing to ensure it is not simply an indulgence of the visions of the CEO and board, and has instead a genuine merit.

Restructuring is a phenomenon that is not restricted to research organisations and has been studied by business management experts. Gary Hamel, for instance, has suggested that companies in trouble change their CEO in a manner tantamount to a 'coup'. This has resulted in expectations of 'genius status' in the new CEO and an abdication of responsibility in ordinary employees for being agents of change. 'Most people's innovation impulses lie dormant as they wait for the great vision to come down from the top' (Kirkpatrick & Hamel, 2004). The explanation is that to enhance the innovation capacity of an organisation takes three to five years, whereas the average CEO expects tenure of three to four years. It is therefore easier to restructure thereby resetting the performance bar, or to do a big deal, than to transform the company (Kirkpatrick & Hamel 2004).

In a review of empirical evidence for organisational theories and repeated reorganisations, published in the Journal of the Royal Society of Medicine, authors Oxman *et al*. (2005) identified reasons for reorganisations and eight indicators of successful re-disorganisations. The latter included 'large consultancy fees paid to friends and relatives' and that 'all the best people have left or are catatonic'. Although the paper was written tongue-in-cheek, there are many truths within it, including an increase in staff turnover whenever reorganisations occur – those with employment choices take them.

Career security

Funding changes and reorganisations have had a significant effect on job security in science in New Zealand and job changes have been reported to have a significant effect on science quality. Research on publication records stimulated by concern that 'a large number of talented people just do not survive in the current system and with the current limited resources...' has revealed that only a small minority of scientists – less than 1% of the greater than 15 million publishing scientists - manage to publish more than one paper a year (Ioannidis *et al*. 2014). The impact of interruption was particularly on the quality of the research produced. Authors with uninterrupted, continuous presence over the 6 years examined (1996-2011) developed a much higher citation impact than other authors, not just because of the greater number of papers published but because of the higher impact of those papers.

Excellent research develops with time and is associated with continuity. Continuity allows in-depth and detailed knowledge of the system under study. Without such knowledge, hypotheses are likely to be flawed, and the research that is developed could turn into a waste of time and money.

A further point for consideration raised in the research was the difference between disciplines. In the cumulative sciences that depend upon the continuous accumulation of relatively small bits of information, uninterrupted and continuous publishing is highly desirable. Biological scientists do their best work in maturity because biological (and hence agricultural) systems are complex, and complexity takes time to understand. Research (Simonton 1999) has shown that poets and physicists tend to produce their finest work in their late 20s, but geologists, biologists, and novelists generally peak much later – often not until their late middle age.

While it is acknowledged that interruption of publishing might be because of choice or life events (e.g. childbirth) Professor Ioannidis also identified limitations and obstacles faced such as insufficient funding, infrastructure or other difficulties that 'create gaps in their productivity or even lead them to abandon science'. He suggested that his work on factors assisting quality of research 'may have implications for the structure, stability and vulnerability of the scientific workforce'.

The implications are already clear in New Zealand in the decline in interest in participation in the sciences at school. Assessment of school students' attitudes to science/mathematics via the Trends in International Mathematics and Science Study[6] (TIMSS) and the Programme for International Student Assessment[7] (PISA) indicates that New Zealand students do not like learning science/ mathematics as much as their international counterparts, and see less value in learning science/mathematics. The authors (Buntting *et al.* 2013) warn that this needs to be considered in light of cross-national response styles (some nations tend to report more at the extremes of scales than others), but also indicate that internationally there is a trend for students from high-achieving countries to report being less engaged than students from lower-achieving countries. A decrease in interest and engagement in science and mathematics from Grade 4 to Grade 8, as measured by TIMSS, is also common internationally, but nevertheless a cause for concern.

Choosing whether or not to pursue science at senior secondary school and beyond is influenced by a variety of factors, including students' experiences of learning science in and out of school, their personal interests and family background, knowledge about the range of study and career options that involve science, and possibly mathematics learning experiences. For some students decisions about science are made very early in their school careers; decreasing enrolments are of concern for the future.

The Future

The Draft National Statement of Science Investment 2014–2024[8] has 'excellent science' as objective one. It includes the statement that rigorous testing (note: of science *per se*, not its infrastructure/management) will include quality, value and impact. Objective two is ensuring value by focusing on relevant science - again for impact. The problem is that 'utility of research' is misunderstood, a gap between fundamental research and impact has emerged, and the CRIs are losing fundamental scientists because of it. The result is that the balance of 'fundamental scientific research' and 'extension', do not match the future research needs.

Fundamental science is needed more than ever before as we shift from an approach of exploiting natural resources to one where we will need to alter resource use efficiency fundamentally (Rowarth & Parsons 2014). Overcoming the challenges currently being faced by New Zealand in productivity, water and greenhouse gas needs a completely new approach. Traditional routes involving only field trials and 'which plants grow better' cannot deliver what is required. It is a serious concern that traditional approaches are favoured most by industry, despite the fact that the problems/challenges they face already demand fundamental knowledge that that approach never could provide.

Fundamental research can have critically valuable practical value. Investigating 'proof of concept' (Parsons *et al*. 2011, 2013) in the first instance avoids wasting vast amounts of money and time in following the wrong path or trying to prove that a hunch actually works in practice.

Scientific research does need translation into farm systems for implementation on farm. But there are considerable numbers of examples (e.g. Caradus *et al*. 2013, Lissaman *et al*. 2013) that show farmers are extremely rapid in their adoption and adaption of new technologies and practices when economic, environmental or regulatory benefits are clear. They are not rapid when the message is confused, particularly when the perceived independence of the results (e.g. if funded by a body with its own commercial interests) is questioned (Caradus 2008). Sadly, the business model has placed CRIs in this category (Edmeades 2004).

[6] TIMSS is a project of the International Association for the Evaluation of Educational Achievement (IEA) and is directed by the TIMSS International Study Center at Boston College in collaboration with a worldwide network of organisations and representatives from the participating countries. See http://timssandpirls.bc.edu/#

[7] PISA is a worldwide study by the Organisation for Economic Co-operation and Development (OECD) in member and non-member nations of 15-year-old school pupils' scholastic performance on mathematics, science, and reading. See http://www.oecd.org/pisa/

[8] http://www.msi.govt.nz/assets/MSI/Update-me/News/draft-NSSI-statement-consultation.pdf

Regaining credibility

The needs for, and organisation of R&D must change as we approach the limits to our capacity to make better use of biological and edaphic/environmental resources. To overcome these resource limitations it is likely that we will need to seek ways to make fundamental changes in the natural evolved biological efficiencies of resource use. This is a far greater challenge in agricultural research than the 'best practice and practical focus' of the recent past; it harks back to the world class contributions of past New Zealand research, hugely enhanced now with new techniques for measurement and new technologies. The challenge for New Zealand remains establishing a system that will enable great people to make that contribution to science, research and development.

On the inevitable calls for 'structuring', Oxman *et al*. (2005) recommend 'establishing an ethics committee to review all future re-disorganisation proposals (again a 'proof of concept' approach) to stop uncontrolled, unplanned (managerial) experimentation'. The Science Manifesto from the Royal Society of New Zealand (National Science Panel, 2008) might assist. There is also a considerable amount of research, on science/business infrastructure design, some of which has been outlined in previous articles in *New Zealand Science Review*.

The principal is, at least at one level, simple. The focus must be on empowering the best people to foresee, plan and conduct, the best possible work. 'Making a contribution', and 'making a difference' is what the most driven of our university and business next generation stress is their greatest goal (after inevitable hedonistic pleasures).

Good science requires full-time pursuit and career length commitment, with funding that is distributed evidently to those of proven ability who can attract and lead active teams enabled to do innovative and creative research. Most countries, including New Zealand, run some schemes to enable this, but proposals to such a fund can require the topic avoids areas of major practical national significance. 'Practical value' to the findings should not be seen as the antithesis of 'highest level of innovative research'; nor should the pursuit of world-class fundamental science be seen as the antithesis of sustaining a vibrant economy in New Zealand. Leaders understand what is required to enable excellent research and innovation: that is what makes them leaders. Of greatest concern is whether the current 'business model', with its emphasis on top-down control and compliance, is impeding the emergence of individuals with the capacity or initiative to lead New Zealand's research and innovation into the future.

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