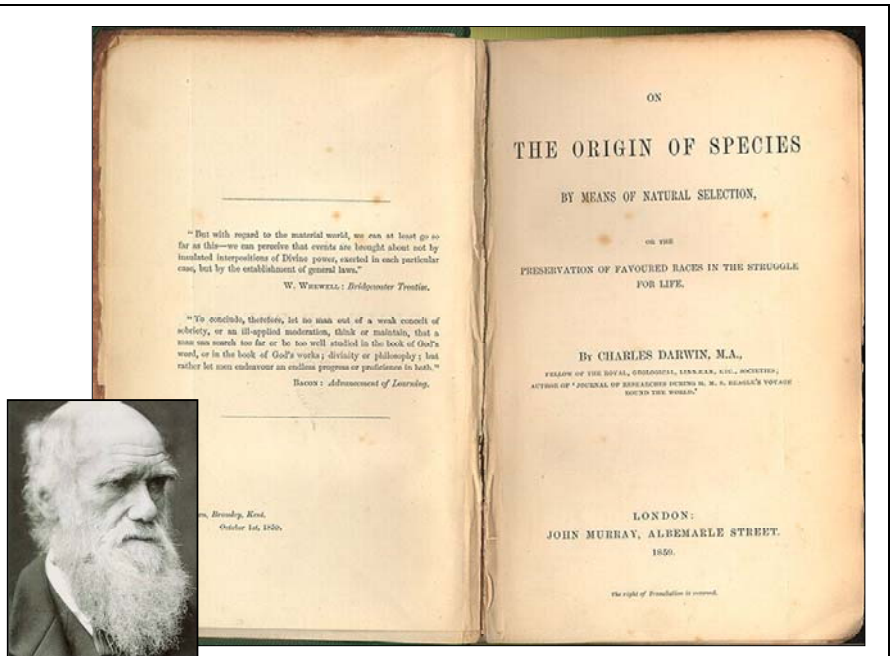
Public lecture: The evolution of science – where is New Zealand going?
26 November 2009 at The University of Auckland

PD Gluckman, Chief Science Advisor

Good afternoon

150 years ago this week, the modern biological revolution started with the publication of *The Origin of Species*.



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Darwin's work did for biology what Newton had done for the physical sciences, establishing some basic principles on which all that has followed in the knowledge revolution is ultimately based. I do not want to fall into the trap of using evolutionary analogies in my talk, as tempted as I might be, because it was the inappropriate use of biological metaphors and superficial understandings that led to the misguided development of eugenics and social Darwinism which ultimately culminated in the horrors of the middle of the twentieth century.

But we should recognise this week for what Darwin's real contribution was – the ability to look at the complex system of structures and relationships in the biological world, to make detailed observations and to create hypotheses and models he was willing to assess dispassionately against the mass of evidence. Some of his ideas such as the unity of life were accepted rapidly, others such as the importance of individual variation and of the processes of selection required a multidisciplinary approach that emerged over the next 100 years.

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Several disciplines were of critical importance – in statistics, our modern procedures of ANOVA owe their origin to Fisher's attempts to solve the issue of the nature of the genetic basis of variation. Later, understanding of the gene arose from the disciplines of chemistry and biochemistry, and most recently advances in developmental biology have allowed a fuller appreciation of the biological underpinning of variation. But there remains much more to understand about the origins of the phenotype – the biology of the individual.

For example, the newly emergent discipline of epigenetics is leading to a major revision of the interaction between gene and environment, and the way cells operate and genes act is itself about to undergo a revolution as new layers of regulation within a cell are being found. And all of this will be impossible to understand without enormous investment in computational biology – investment that New Zealand must make if we are going to stay competitive in the biological sector. I will return later to the topic of national scientific infrastructure.

And what started off 150 years ago with a gentle polymath who retired to the countryside to spend 10 years studying barnacles has emerged within a relatively short time as the fundamental basis of understanding the living world – be it dealing with the emergence of HIN1 or antibiotic-resistant superbugs, exploring how obesity, diabetes and mental disorders could result from our inability to cope with the huge differences between the Palaeolithic and the modern era, using concepts of selection as the basis for our dairy and horticultural industries, or assessing the challenges of using genetically modified crops or organisms to respond to climate change or food shortages.

I start with this introduction for many reasons. First, the anniversary without doubt marks one of the most important events in our scientific history and as an evolutionary biologist I would be remiss in not recognising it.

Second, not even Darwin could have predicted the extent to which his discovery would have impacted on so many disciplines – he did not refer to medicine at all in his writings yet its relevance is very obvious, and he would have been amazed by its indirect effects on statistics. This should remind us that science so often has its major impacts a long way from where it started.

Third, it reminds us that any scientific breakthrough has its downsides, and for evolution the downside was the misapplication of Darwin's ideas to provide a spurious scientific basis for eugenics.

Fourth, scientific progress can cause discomfort to the public, as indeed evolutionary biology continues to do for those of certain beliefs, and we still see this in many domains, particularly those relating to genetic technologies.

Finally, here is a good demonstration of how science is a story of parallel discovery – Darwin and Wallace – and requires new technologies, multiple disciplines, and the right people for its exploitation – Fisher, Morgan, Johansson, Wright, Dobzhansky, Watson & Crick, Mullis and many others; and yes a number of New Zealanders, for example Maurice Wilkins and Allan Wilson.

But in the end perhaps we were lucky – Darwin was independently wealthy, he did not need grants, and he could sustain his focus for 50 years. I could stretch the analogy further but will resist the temptation. Nevertheless, it forms a useful introduction because I do not want anyone to believe that in any way I am downplaying the role of basic science.

My role as Chief Science Advisor is new and this has both an upside and a downside. The upside is that what I do is not yet fixed in stone but the downside is that the appointment has led to numerous expectations, many of which I cannot meet. In the end my role is simple – to advise the Prime Minister and thus to be a voice representing science in a variety of discussions. I have no executive function.

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This is very different to the role of the Minister of RS&T whose responsibility is for the explicit components of the science system such as the Foundation and the Crown Research Institutes.

In my role it has become manifestly clear is that science is absolutely cross-sectoral, and assisting government in that dimension is emerging as an important part of my work. There is probably not a Ministry or Agency of the Crown for which science and the scientific approach is not important, or indeed critical. In Ministries as diverse as Social Welfare, Environment, Justice and Economic Development, there is a refreshing level of understanding of the role that science and knowledge must have.

There is the beginning of the recognition that there is a far greater need for evidence to be rigorously based and inform policy formation, although I hasten to say that there can be many cogent reasons why evidence and policy need not align: the evidence may not be complete, the public may not accept the evidence, it may conflict with the accepted values of a society, the cost implications may be contrary to the approach supported by the evidence, and ultimately the democratic process will put constraints on decisions that can be made.

The important point, however, is not to deny the evidence but to acknowledge it and explain when and why policies are developed that are not in accord with the evidence. Next year a significant part of my work agenda will relate to thinking about how we can improve the use of evidence by government, and indeed the Prime Minister has already approved a pilot project which has a number of University of Auckland faculty working on it: namely, to explore the evidence that might inform how to improve the transition of young New Zealanders through adolescence.

My goal is to try in an unbiased way to look at the evidence that explains why New Zealand adolescents have such high morbidity – second only to the USA – and to identify what we know about childhood and adolescence which might impact on policy settings in health, education, social welfare and justice that might lead to better outcomes.

The evidence will be reviewed without bias and used to inform a report on what it implies, either for policy action or more research. I expect some counter-intuitive and challenging results. Beyond that, I will be looking at what kind of general protocols might make sense in evidence-based policy formation.

But let us focus on the science system. It would escape no-one's attention that there is a more intense focus on the science system now than there has been for well over a decade. That attention is very healthy, and reflects a growing realisation that expenditure on science must be seen as an investment in our country's future rather than as a cost.

But it is clear that we need a multiyear strategy with a planned approach – it is not as simple as just giving more funds to the public science system. The system itself is part of the problem, and there are manifest gaps in our investment portfolio if we are to get optimal returns from our science investment. These are issues that need to be addressed.

As the Prime Minister has made clear, our low productivity is at the heart of our national challenge, and our chronically low investment in science is now acknowledged as playing a significant role in that poor productivity. This set of slides makes the point well. The first two just make a simple comparison with Denmark, a country of similar size which had an economy like ours just two decades ago – agriculturally based.

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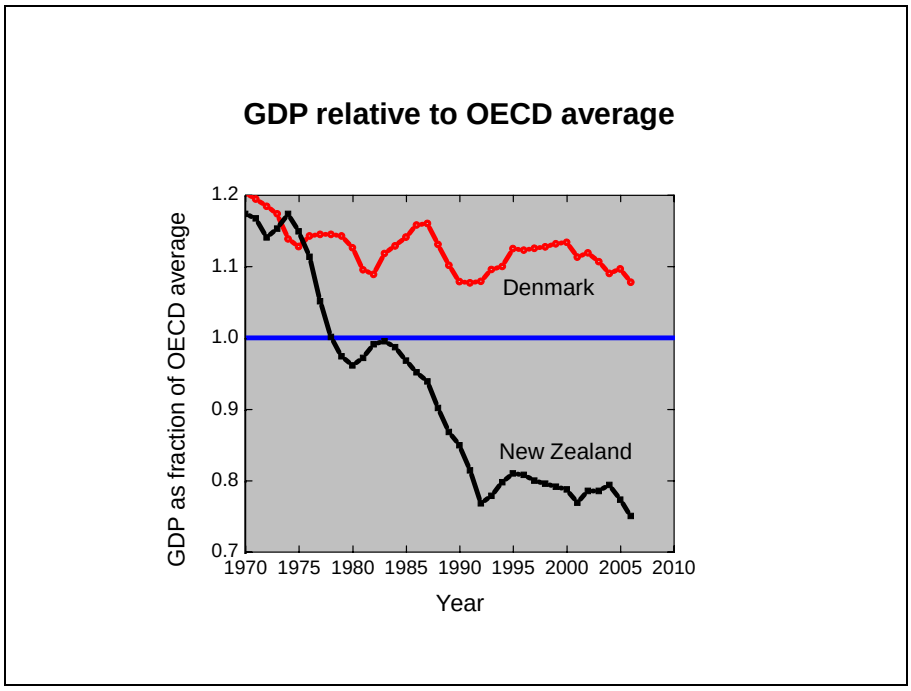

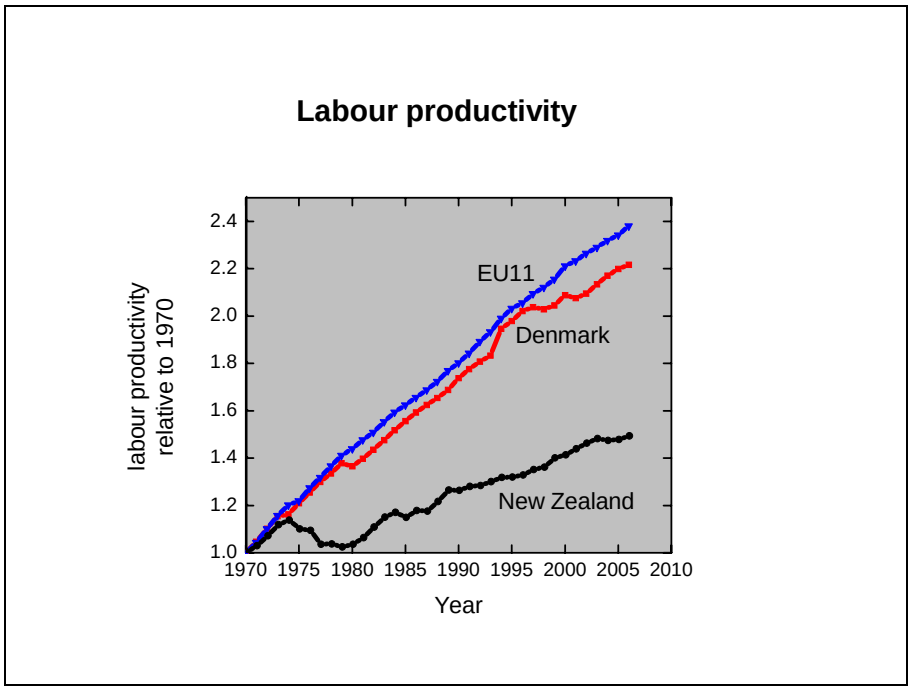

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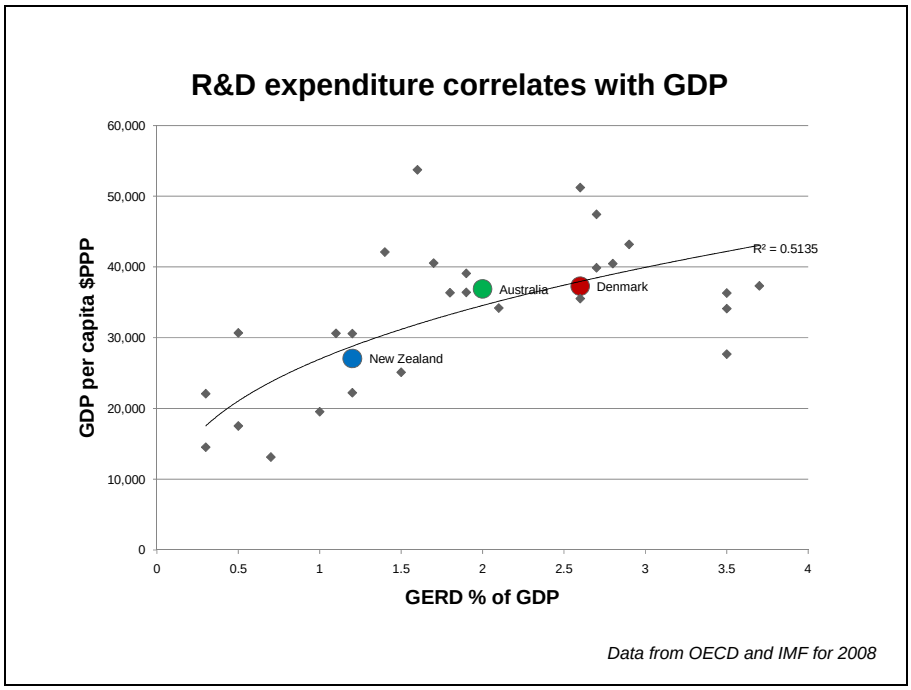
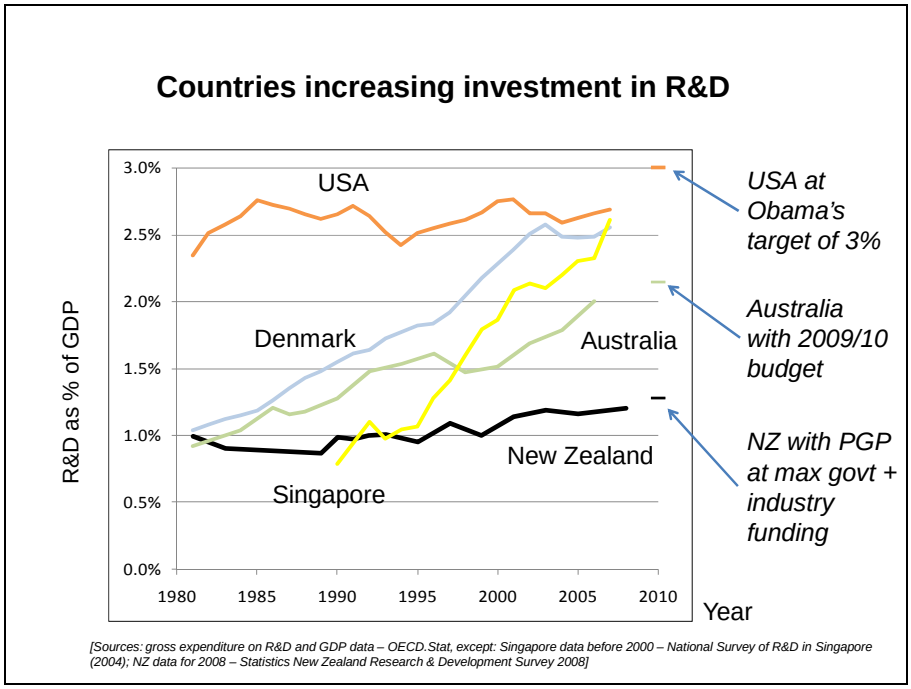
This next slide is telling – nations that invest more in RS&T are the most productive.



I do not want to fall into the old trap of association and causation, but while in the past it has been argued that this relationship reflects the fact that more productive countries can afford to undertake more RS&T, the view now would be essentially unanimous that there is a causal relationship in the other direction, namely that investment in RS&T drives innovation and productivity.



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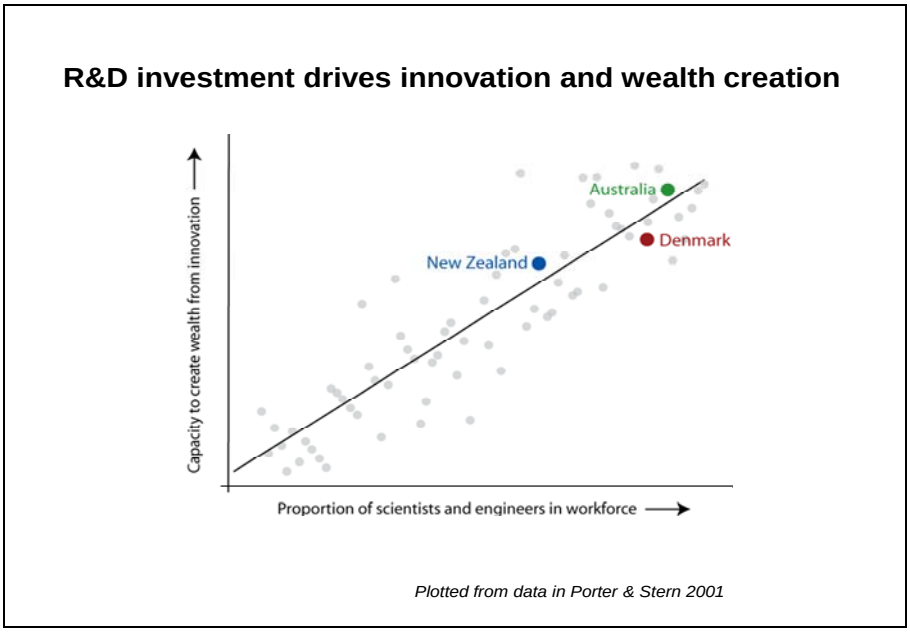
And the next slide shows something else – that while over the last decade other nations we like to compare ourselves to have made significant investments in RS&T, we have sort of drifted along.

Denmark, Australia and many other countries have really lifted their game and continue to invest even in fiscally constrained times.

We have now had incomprehensibly low investment in RS&T over perhaps three decades.

Why is this the case?

- Is it that we are a young country which has not learnt to value intellectualism?
- Is it that we are too egalitarian?
- Is it that we were too lucky as a country in the immediate post-war period; we could grow the food Britain wanted and as a result we established other priorities in government expenditure that are now entrenched and hard to shift?
- Or is it that we never had the patience to accept that there would be a minimum of a decade between RS&T investment and any hint of return?



But the story is a bit more complex: this plot of the number of scientists in the workforce against innovation capacity shows a much more linear relationship and this is arguably a proxy for private sector investment.

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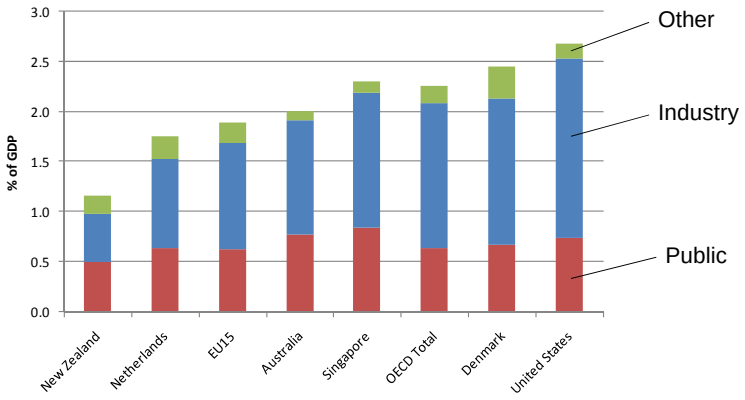

Source: OECD Main Science & Technology Indicators database for 2007 or latest year

And this slide shows this in some detail – our absolute public investment in RS&T is poor but proportionately it is very high because our private sector RS&T spend is very low indeed. And OECD figures suggest that it is the private sector spend that has the larger impact on productivity.

So what is going on – why is it that our private sector spend on RS&T is so low? Is the solution simply to support private sector RS&T?

But perhaps low public sector investment over many years without appropriate incentives in place might have dis-incentivised the private sector from seeing RS&T as important because there is insufficient ideas flow, and certainly not enough staff.

Graduates (NZ)

	1999 (%)	2006 (%)
Nat & Phys Sci	2518 (11.2)	2646 (10.8)
Agric & Environ	401 (1.8)	355 (1.4)
Business	4396 (19.6)	4916 (20.0)
Creative Arts + Soc & Culture	6710 (29.8)	8102 (33.0)

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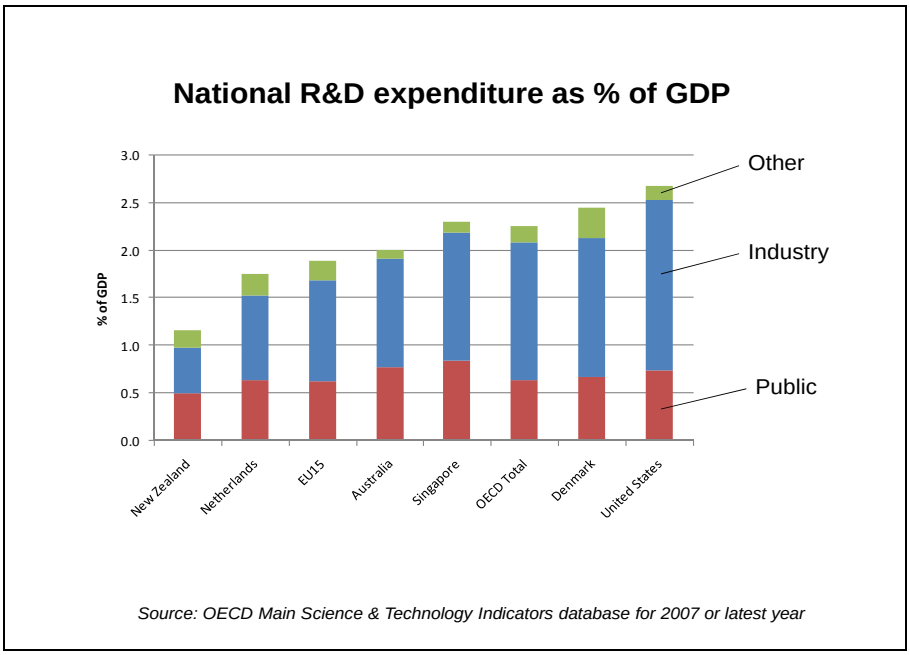
This slide is most worrisome – it shows where our tertiary sector is producing graduates; we have a major capacity and capability gap. But this gap will not fill unless the opportunities exist and unless the potential rewards in science and technology are sufficient.



But back to the question of private sector RS&T investment. Our funding system has been extraordinarily focused on private sector-directed public sector research.

The Foundation approach is arguably more end-user orientated than any other science funding system in the world, yet two decades on its approach appears to have failed. Has a public sector science system too focused on the private sector displaced private sector investment?

Or is it simply that our mix of firms is such that we do not have the large firms in the defence and pharmaceutical sectors that drive so much RS&T elsewhere?

Or have we got institutional blocks at different levels which limit public to private transfer of knowledge and thus limit the capacity of companies to take it to scale?

But underlying all of this is the distorted nature of the New Zealand capital and investment market, which does not favour longer term investment.

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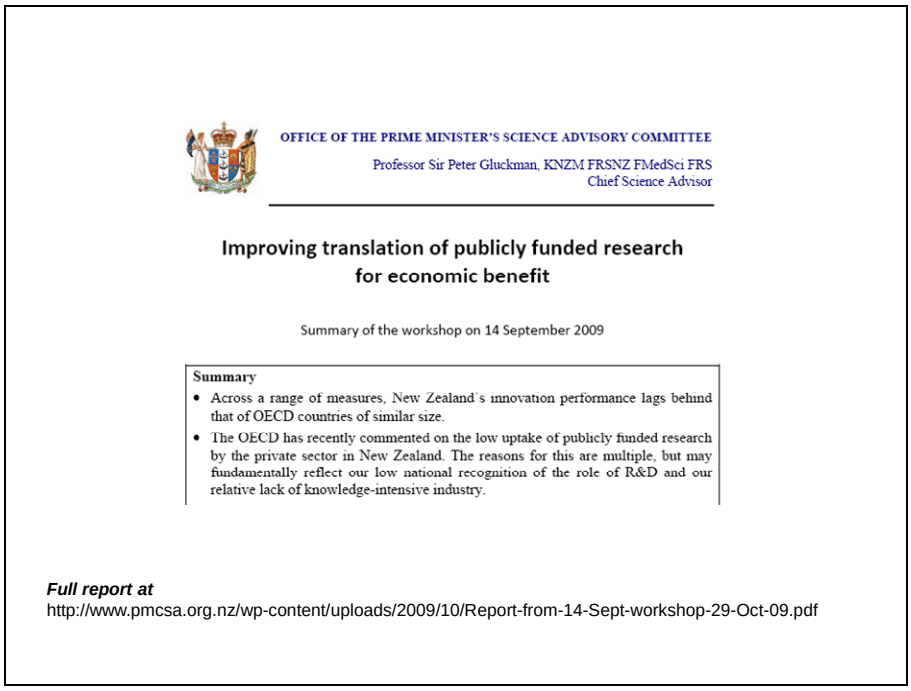

OFFICE OF THE PRIME MINISTER'S SCIENCE ADVISORY COMMITTEE

Professor Sir Peter Gluckman, KNZM FRSNZ FMedSci FRS
Chief Science Advisor

Improving translation of publicly funded research for economic benefit

Summary of the workshop on 14 September 2009

Summary

- Across a range of measures, New Zealand's innovation performance lags behind that of OECD countries of similar size.
- The OECD has recently commented on the low uptake of publicly funded research by the private sector in New Zealand. The reasons for this are multiple, but may fundamentally reflect our low national recognition of the role of R&D and our relative lack of knowledge-intensive industry.

Full report at
http://www.pmcsa.org.nz/wp-content/uploads/2009/10/Report-from-14-Sept-workshop-29-Oct-09.pdf

One of my early tasks for the Prime Minister was to explore the barriers to private uptake of public sector-sourced RS&T. There are many. Essentially it is in part cultural – public sector researchers have different rules and incentives from those in the private sector, time horizons are different, the linearity of objectives is much less for the academic.

We have little staff exchange between the public and private sectors, and we need to find ways to enhance that. As a result, companies tend to come to researchers late to solve a particular problem rather than have an early dialogue about where science is going and how it might transform their firm.

Then there is the Performance-Based Research Fund. There is debate as to the extent to which the PBRF inhibits academics from entrepreneurial and commercial activity – the concern may be overstated about the PBRF *per se*, but there can be no doubt that university promotion systems and grant assessments from bodies such as the Health Research Council do disadvantage those with heavy commercial involvement. We need to find ways through this barrier.

In the UK there is now a major move to address this issue with a new research evaluation format. The UK already has a fundamental difference in its system, being "research unit"-based rather than "individual"-based, and there is in my judgement much value in such an approach.

Perhaps we can refer to the current consultation document in the UK, where I have paraphrased the relevant sections.

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The UK Research Excellence Framework

- "Should continue to incentivise research excellence, but also reflect the quality of the researcher's contribution to public policy making and to public engagement"
  and
- "Not create disincentives to researchers moving between academia and the private sector"
- Assessment of research outputs will depend on three factors:
  - ***output quality*** assessed by traditional measures
  - ***impact*** which is defined as economic, social, public policy, cultural and quality of life impacts
  - the concept of ***environment*** – that is, the quality and sustainability of a unit's research environment, its vitality and wider engagement beyond the institution and discipline

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- the concept of ***environment*** – that is, the quality and sustainability of a unit's research environment, its vitality and wider engagement beyond the institution and discipline

Perhaps this reflects a more mature statement of what universities should be doing than our own system, which still focuses on individual ego and where the major outcome of the system has been to drive positioning of universities for recruitment rather than to reward behaviours that meet the key objectives of why the public funds universities – as generators of both scholarship and research, with roles in general and specialist education as well as being critical institutions in advancing the intellectualism of the societies they live within.

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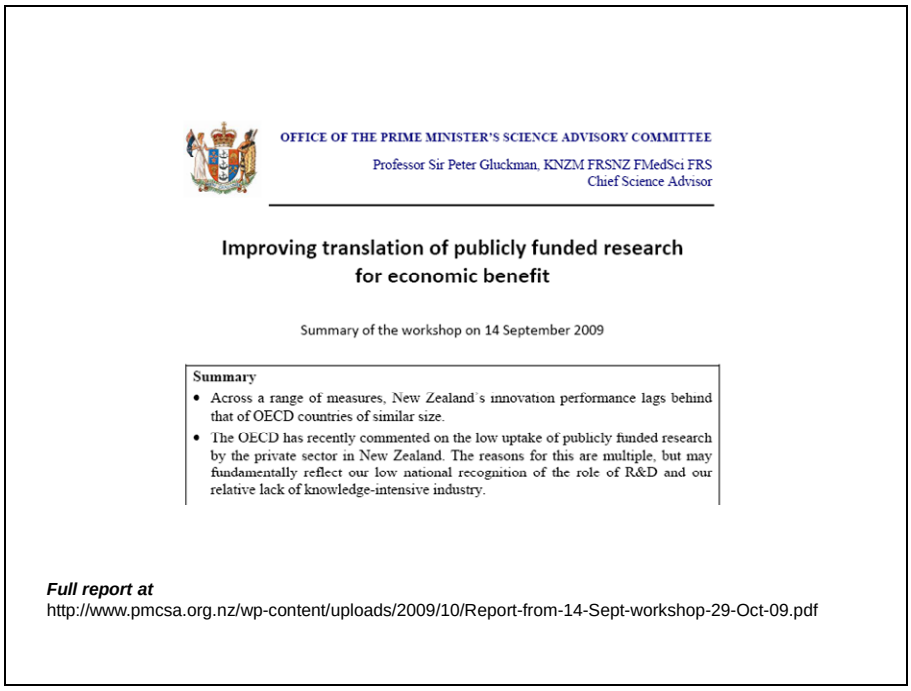

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A large part of my report focuses on the issue of technology transfer – the export of knowledge out of CRIs and universities to business. Part of that must be through open innovation. That is, universities and CRIs must get better at making knowledge freely available to firms and maximising the value of their work for "New Zealand Inc".

Particularly given the low number of technologists and scientists in the private sector, we must really put effort into how extension activities operate within the New Zealand system. For example, would investment here be more important or more effective in the short-term than non-discretionary support of business through, say, tax breaks?

One of my current work programmes is to look at these issues of open versus closed innovation in the public sector. This issue extends beyond a narrow focus on intellectual property. In many jurisdictions, including the UK and Singapore, public funding comes with the obligation to share materials and data yet there are many examples in New Zealand where the culture of competition has led to duplicated research within the public domain or valuable research just unable to be done. You may be surprised how rapidly big industry is recognising the ecological value of open innovation.

A real issue is the lack of expertise in technology transfer – this is a particular skill and we have few practitioners of it in New Zealand. We are very lucky in Auckland that Uniservices is seen to be professional, productive and of international standing.

Other nations have tended to consolidate this activity in different ways – through hub and spoke models or centres of excellence. We cannot possibly have thirty effective technology transfer operations in the public sector.

We also have no differentiation by domain – a deal in biotech is very different to a deal in software. We need translators in every institution but the real high-level expertise in deal making and in IP management may need more sharing. Work is needed here.

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The related activity is that of business assistance – there is work under way led by the Ministries of Economic Development, RS&T and Treasury in this area and I cannot comment further. The issues go beyond affordability and include issues of principle – for example should it be a broad entitlement through tools such as tax breaks, or is a more discretionary grant-based approach needed. The policy issues are complex.

In my early months in my new role I focused on asking three questions:

- ***Why should New Zealand undertake research?***
- ***How should a small country distant from markets and global populations undertake research?***
- ***How should we take that research to scale?***

To which I must now add the fourth question: where should we place the investment priorities?

Dealing briefly with the first question, we should understand that science adds value to New Zealand in many ways – a knowledge-based society will be more ambitious, more prepared to face the challenges ahead, more able and willing to address issues of social development and environmental protection, and certainly more productive.

The question of scale is critical. New Zealand cannot thrive with just one Fonterra; we need to see greater productivity extending beyond our shores in several domains. Seeing where that productivity growth will be is complex, for we face the peculiar challenges of distance, size, and lack of internal markets. We have to become clever about using our resources – our well educated people, our ability to grow grass and ruminants, clean water, our minerals, our closeness to Australia, our strengthening umbilical cord to Asia.

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We have to work out where will our capacity to export will really grow – will the food industry in 20 years be focused more on food for health, what can we do with our mineral resources, how should we respond to global warming, how can we export services better? We need to become clearer about what we can do well on our own and where taking it to scale will require international partnerships from an early stage.

Will we do better trying to grow a hi-tech industry on our own or, in an age of parallel discovery, will we do better by partnering from the discovery stage? If we are inventing something, there is a high probability that so are the Singaporeans or the Chinese or the Americans – should we be seeking more formal and closer ties with other research communities from the earliest stages?

So how should we do research?

Some of the issues are addressed in the consultative document on strategic priorities for the science sector issued by the Minister of Research, Science & Technology. This is a very positive step – for the first time in a long time there is clarity as to where the science system is to be positioned and the paper makes some very important points.

The document has three sections. The first, and the one I want to focus on, includes a list of thirteen strategic principles – they are listed on these slides. The first strategic principle is that of excellence and impact – note again the use of the word **impact**.

The paper acknowledges that the science system has been over-competitive and that this has had counter-productive effects. It looks towards a better balance of approaches.

It acknowledges at the start the value of science beyond direct economic productivity for public good, for environmental protection and, for social development.

The paper also makes the argument for simplification and rationalisation and I expect we will see moves in that direction in due course.

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But the document also makes another critical point. We cannot do everything. We are only 4 million people and we have to make some choices. That is why we have priorities. That is why we have to scenario test where major research investment is likely to have greatest impact. But again the document shows a realism which has for some time been lost – the system must be responsive and flexible and acknowledge the essential role of basic research and serendipitous research findings. But again we have to get real as to where are the research domains that will transform New Zealand, for we need a transformational rather than an incremental strategy.

Where are our most likely successes going to come from? Food of course, but in what way – how can we return more to the farmer, how do we deal with the challenge of pastoral emissions? Can we transform our service sector to export more services, how can we extract value from our mineral-rich and water-rich land yet protect the environment, could we find a manufacturing niche? In twenty years we could well be primarily an exporter of ideas, but how to do we capture value?

And the priorities list goes further; it sees the importance of international strategic partnerships. A few days ago the CEO of the Ministry of Foreign Affairs & Trade, John Allen, and myself co-chaired a meeting of leaders of ministries, agencies, universities and CRIs to consider how we can use science better to leverage New Zealand's position in the world - we need to ensure our relevance to others and how to protect and develop our diplomatic and trade interests.

Science is a key weapon in our armament but we have not used it well. The discussions emerging about the Square Kilometre Array and the way we plan to address pastoral emissions show the essential need for an international strategy.

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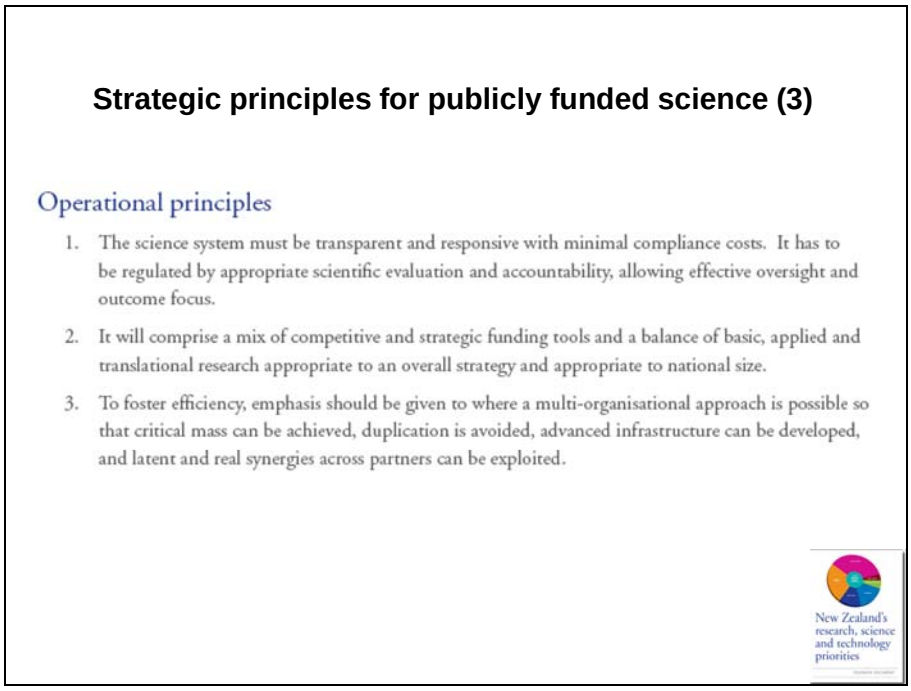

The Minister's document recognises that for too long our research providers have been focused on institutional health and bottom lines, rather than seeking synergies through inter-institutional activity. It highlights the need to have a "New Zealand Incorporated" approach.

But how do you do that while maintaining institutional health? The Centres of Research Excellence were a good first move in that direction – this is a fundamental shift in thinking beyond institutional boundaries. It is the only way we will get to scale.

Climate change represents a particular challenge. New Zealand is the only Annex 1 country with the major part of its emissions being pastoral. We and the developing world have to address this, and the Prime Minister has announced his desire to see a global alliance focusing on this issue with New Zealand taking a lead role, particularly in the area of ruminant emissions.

We should not underestimate the importance of this scientific challenge – it will emerge to be an area impacting on many dimensions of science. The form and shape of the alliance is yet to emerge and it will be an area where institutional interests will have to be submerged for national interest. I emphasise this again because science in New Zealand can harm itself with its strong focus on institutional health rather than what the science can deliver.

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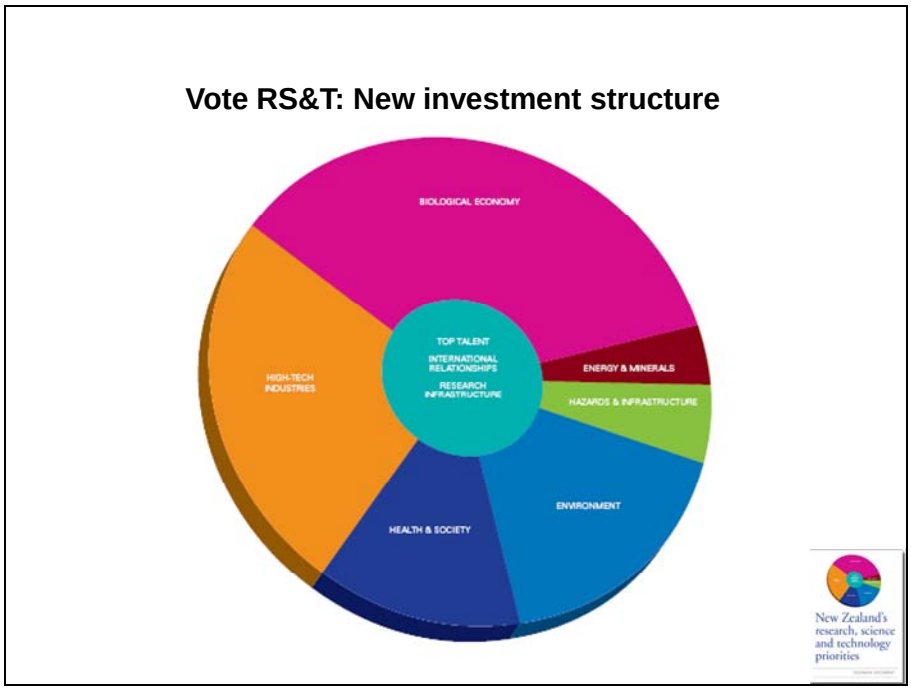

The third part of the document highlights areas where there is work to be done. It is the bull's-eye in this figure, which is a description of the science system as it stands now. The outer ring shows where the state largely spends its money, but it is the bull's-eye that we have to address and expand: how to retain and recruit entrepreneurial talent, how to sustain an infrastructure and how to leverage science not just nationally but so we are relevant to the world and so our knowledge-based industries can get to scale.

The issue of talent is a real worry and I am currently addressing this in a report to the Prime Minister. It has multiple layers – we urgently need an aggressive strategy to attract and retain some leading intellectually entrepreneurial scientists. What impact would science have for New Zealand if our universities and CRIs housed not just one but 50 Peter Hunters? Could it be done?

Just look over the Tasman to what was once an intellectual backwater even by our standards – Queensland – or to a country we were giving foreign aid to only a generation ago – Singapore. This is not just about salary packages; it is about the scientific environment, the infrastructure, the commitment to clustered expertise. And beyond this how do we attract emergent scientists to stay and ensure a better pipeline than we now have?

We have a very run-down infrastructure and increasingly there are areas where major infrastructure is needed. We have deficient capacity to use modern imaging to study livestock, we have obvious gaps in high performance computing, are we truly equipped for the bioinformatics age or to develop foods for health?

Our deep sequencing capacity nationally is less than what might be in a single laboratory overseas. We do not have a clear approach to infrastructure and what principles should operate – infrastructure without running costs and allowance for depreciation has no value.

What should we do together with Australia – the synchrotron is an example of a joint infrastructure – or should we have national resources, for example a national high performance computing centre? How should infrastructure be governed and how should we cover the costs – these are issues that merit reflection and work is under way.

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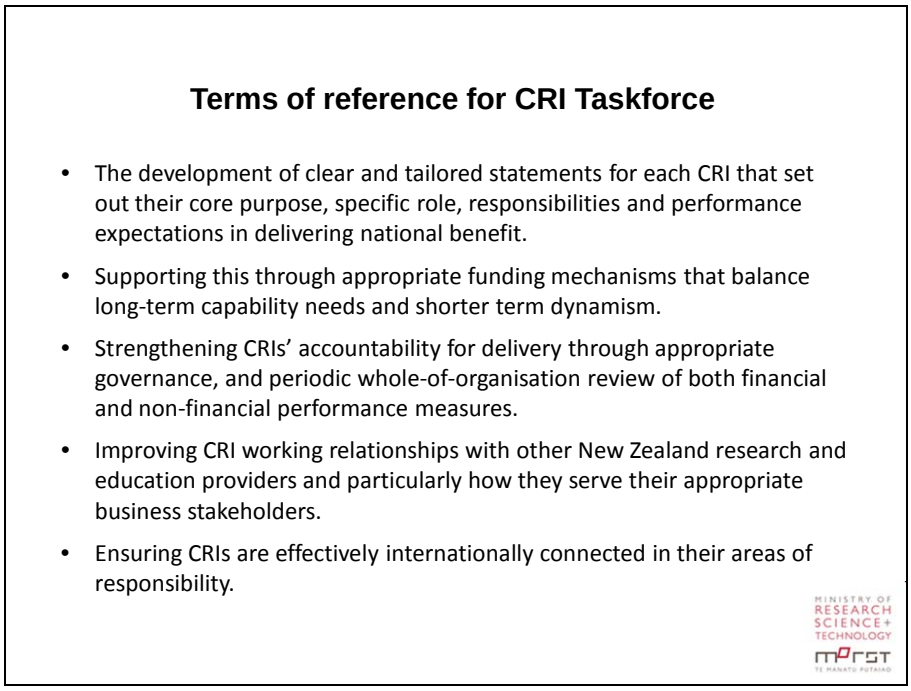

A related effort also under way is the CRI Taskforce. Do we have the balance of interests right – have we compromised the capacities of CRIs to deliver with narrow performance measures, a lack of scientific advisory boards, and an over-competitive funding system? CRI boards are unclear about their missions and even if they were clear they have little capacity to control their destiny as they do not control their funding.

CRIs are essentially acting as research hotels. Yet their missions could be easily defined – to support their sectors with the medium and long term research that is required for those sectors to thrive, and to provide shorter term assistance to firms.

It would be inappropriate for me to comment more on the CRI Taskforce other than to say it is a major and important exercise and is intended to lead to a much improved ability of the CRIs to deliver quality research, to support their sector, to be nimble, flexible and responsive and most importantly of all to be *research* institutes with better links to universities and firms.

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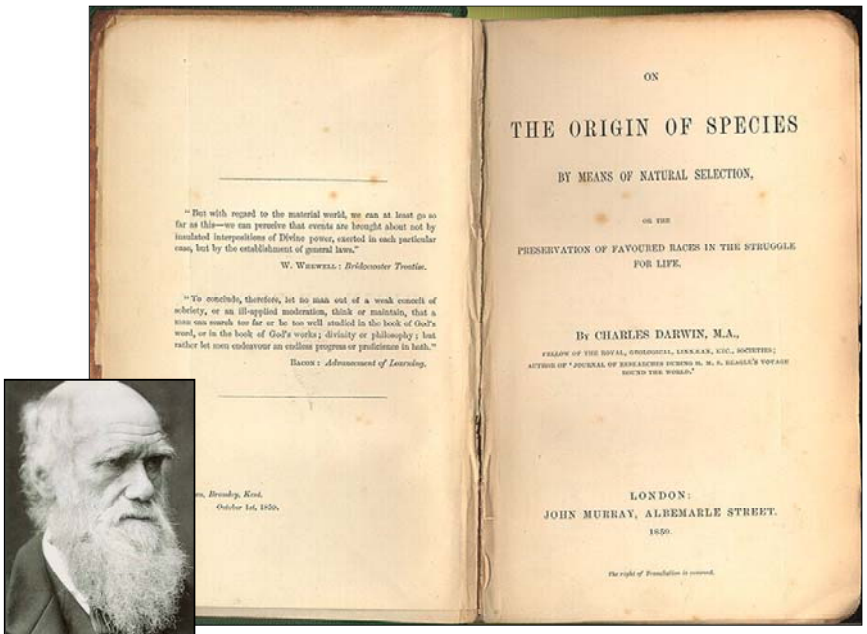

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I started this lecture reflecting on Charles Darwin. The ideas he generated have in no small part played a role in changing the nature of science itself. In the public mind the science of the 1960s was about certainty – maths, physics and engineering. In 2010 science is about uncertainty – it is about complex systems – ecology, global climate, human reproduction, nutrition and disease, regenerative medicine, genetic modification, viral epidemics, nanotechnology. Much of our science is almost incomprehensible to ourselves – how many papers in *Nature* or *Science* can you comprehend even if they are in your discipline? The science we do impacts on people's lives – and we cannot always predict how.

Science is no longer done when the paper is published. Rather, science is only done when there is a consensus between scientist and public, and that is not always easy to achieve. Look at the folate debacle. Scientists have to spend more time learning to communicate across disciplines and between themselves and the public, and that means listening as well as telling. The age of the patronising scientist is gone.

But as we engage with the public more we face another problem – that of hyperbole, that of over-stating what we have done and its implications. How many times have we cured cancer? We do not serve the public well by being immodest, we somehow have to get the media beyond breakthrough stories or the self-serving stories we have all used to get publicity for our institutions or to influence a grant process. It is difficult because our media loves breakthrough stories but science does not move in a series of breakthroughs – it is slow and non-linear, yet consensus and new understandings somehow emerge.

Transmitting that to the public and thus to the politician is a skill and we need a new kind of partnership between academics and the media. It is a challenge I will be picking up next year.
The Prime Minister has repeatedly stated his belief that science is central to New Zealand's innovation strategy. The issues I have discussed above show that a review of the public science sector in New Zealand is underway. The sector will not change overnight, but over time science will play a more critical role in our transformation as a nation. The consequent readjustments will require many of us to move beyond our comfort zone, but we cannot squander this opportunity.

THANK YOU.

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