Attention:
Future Pathways Policy Team
Ministry of Business, Innovation & Employment

Submission on:
Future Pathways Te Ara Paerangi Green Paper

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Privacy - 9(2)(a)

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Thank you for the opportunity to provide comment on the above-named green paper from the Future Pathways Policy Team.

My background is in molecular biology, microbiology, and evolutionary biology. I have worked overseas and have had the opportunity to train and work in science several languages. On returning to New Zealand, I benefitted from funding via a Rutherford Discovery Fellowship, a scheme established to support early career researchers. I am now an independent mid-career researcher running my own research group with national research funding.

Having read the 'Te Ara Paerangi Future Pathways Summary 2021', I wish to comment on several matters raised therein that I hope can be of benefit to your policy team in developing a 'connected, resilient and adaptable modern' research system for Aotearoa New Zealand.

The major points I wish to make are summarised below. I provide a detailed discussion of each in the following pages.

1. Increase internationally competitive, investigator-led basic research funding.
2. Distinguish between the mission-led activities of CRIs and investigator-led applied research.
3. Take a careful look at the challenges presented by Mātauranga Māori and its interface with scientific research. This cannot be advocated without careful understanding of the implications.
4. Avoid 'benevolently racist' policy that would narrow opportunities for Māori, Pasifika or other minority groups to engage in areas of investigator-led research of their choosing.
5. Create greater opportunities for scholars from anywhere in the world to pursue research in New Zealand. Do not require such work to be aligned to strategic areas of interest to the government of the day.
6. Improve funding options for early-career investigator-led grants that makes them attractive to their institutions. This requires full funding for salary.

1. Increase internationally competitive, investigator-led basic research funding.
It is well accepted that the path from basic research to its application is most often unclear. Two examples where basic curiosity led to transformative applications include:

- The development of blue LEDs (**Nobel Prize 2014**) which later enabled the creation of LED-based smart screens.
- The discovery of Green Fluorescent Proteins, which are responsible for bioluminescence in jellyfish (**Nobel Prize 2008**). These proteins have since been used to revolutionise several fields, including medical and cellular imaging, and synthetic biology.

The value of such research is only understandable in hindsight because the applications and the path to those applications were not evident to the researchers at the time they initiated their work.

Such investigator-led research is central to a successful research system that 'attracts and retains excellent talent'. In 2014, I was one of 39 Rutherford Discovery Fellows (from a total of 40 recipients), who submitted a response to the National Statement of Science Investment. Our submission, which we publicly released, is provided in **Appendix 1**.

One of three key points we made was:
Greater expenditure on investigator-led funding is required if New Zealand is to develop into a strong and prosperous advanced economy. This must happen in the short term.

We proposed that this could be achieved by increasing the Marsden Fund to allow the top 20% of applications to be funded. I note that our rates are 11% for Fast Start grants and 10% for Standard grants. These success rates remained at this level for the past 9 years.

This fund is needed to remain internationally competitive in research, and in training of the next generation of researchers.

Proposed action: ***Increase the Marsden Fund success rate so the top 20% of applications are funded.***

2. Distinguish between the mission-led activities of CRIs and investigator-led applied research.
Applied research is important to the NZ science system. It is very important that this remain a feature of the research environment. The MBIE Endeavour fund, particularly for Smart Ideas, should be retained and protected as an investigator-led funding source. It is important that this be primarily focused around investigator-led ideas that can help progress research towards application, but can also explore early-stage potential for application.

Both Marsden and the Endeavour Fund will work best if they are kept independent from government policy objectives, national research priorities, or political goals such as those articulated in the Green Paper or the National Statement of Science Investment from 2014.

Proposed action: ***Reimagine the Endeavour Fund as an investigator-led applied research fund.***

To achieve this:

- **Make the Endeavour Fund explicitly for researching potential applications.**
- **Remove the requirement for funding to align with investment priority settings.**
- **Ensure funding is awarded to the top 20% of grant submissions.**

3. Take a careful look at the challenges presented by Mātauranga Māori and its interface with scientific research. This cannot be advocated without careful understanding of the implications.

Incorporation of Mātauranga Māori into science has been a controversial topic over the past year. There are two important points that must be considered from my perspective as a scientist.

(i). There may be areas of Mātauranga Māori that can be hugely beneficial to science. The best international example to be aware of is the development of artemisinin, an antimalarial drug discovered by Tu Youyou, a Chinese researcher who followed leads she found in traditional Chinese texts regarding the use of wormwood for treatment of illness. She won the Nobel Prize for this work (**Nobel Prize 2015**). Note however that Chinese traditional medicine is also known for a large number of pseudoscientific remedies and practices of no medial value, some of which are known to negatively impact biodiversity through the collection of endangered species for their preparation.

To do as China has done and begin exploring the full potential of rongoā (traditional medicine), we need to create the conditions for a discovery of the magnitude of artemisinin. Importantly, this also requires such research to have the possibility to question and discard remedies that do not stand up to the kind of careful and rigorous research and testing required to bring a new drug to market.

(ii). Mātauranga Māori cannot be the partner of science if it cannot be questioned and challenged. This will require a difficult and delicate conversation. Other countries have undertaken this challenge and we need to learn from them.

I provide as an example a piece (in draft form, which is to be published in 2022) on the development of science in Japan, where one side of my family is from. In **Appendix 2** I provide examples of where the traditional knowledge of Japan came into conflict with science, but also examples where traditional knowledge and science have created new knowledge.

I make a final point on this tension because there are some suggestions that we must keep Mātauranga Māori sacred and not open to question and test. This position in effect means it must be accepted on faith. This is to treat it as a religion, not to be challenged. If applied to all areas of Mātauranga Māori, such a decision makes it incompatible with science and research. In Appendix 2, I point out that some parts of Mātauranga Māori are similar to Japanese traditional thinking that fit this non-scientific description. Such areas can be kept separate through what are known as non-overlapping magisteria, because they deal with different domains. To bring Mātauranga Māori into the research system, and scientific enquiry in particular, we must be prepared to separate these components out.

Proposed action:

- ***Investigate whether there is appetite to create the conditions where Mātauranga Māori is able to be subjected to direct test, or whether its practitioners or supporters instead require that it be afforded special status, protecting it against tests that may falsify or discredit specific claims.***
- ***Acknowledge that Mātauranga Māori can only contribute to global knowledge if subjected to testing; it cannot be equated with scientific enquiry if it's claims about the world are protected. If some parts can be subjected to test, these must be distinguished from those parts that are religious in nature.***

4. Avoid policy that would narrow the opportunities for Māori and Pasifika or other minorities to engage in areas of investigator-led research of their choosing.

The discussion of science and Mātauranga Māori, or other traditional knowledge, if not carefully negotiated, can lead to an unintended expectation that members of the ethnic groups from which those areas of traditional knowledge derive should preferentially work on these topics. Some may choose to do so, but it is absolutely essential that policy or funding opportunities do not lead to a narrowing of opportunity. Māori, Pasifika, or members of any minority group for that matter, should have the same opportunities to work in any area of their choosing as anyone else. To not do so is to espouse a form of 'benevolent racism', where good intent inadvertently narrows opportunity on the basis of ethnicity[1]. To ensure that such equality of opportunity is protected, it is critical that our investigator-led research ecosystem is strengthened through greater funding, and that we avoid creating conditions where minorities are encouraged to work primarily in areas we perceive as pertaining to their group, rather than allowing them the opportunity to work in any area of their choosing. I would personally be horrified if I were only able to or actively encouraged to work on areas of research of direct relevance to my Japanese heritage, while others did not have such a restriction.

Proposed Action: ***Do not create policy that incentivises researchers of a certain ethnicity to primarily work in areas prescribed by that policy.***

5. Create greater opportunities for scholars from anywhere in the world to pursue research in New Zealand. Do not require such work to be aligned to strategic areas of interest to the government of the day.

New Zealand currently enjoys a strong international reputation as a desirable place to study and work. Other countries have progammes in place to attract top students and scholars to study for advanced degrees, and to undertake employment at the beginning of their research careers. This forms a strong bond between New Zealand and future research leaders during their formative years. Currently, such opportunities are limited, which means we fail to capture the talent of those who are willing to come to our shores and contribute to our research activities. For instance:

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[1] https://nzareblog.wordpress.com/2019/07/01/benevolent-racism/

- The Rutherford Discovery Fellowships can only be applied for by researchers with permanent residence or citizenship. This excludes capable international researchers working in New Zealand who do not have residence or citizenship status.
- Our international PhD scholarships are very narrowly focused. The NZ International Doctoral Research Scholarships (not currently being offered by Education New Zealand) have only offered opportunities in very narrow areas of scholarship.
- There are very few mechanisms for internationally trained early career researchers to come to New Zealand. Other countries have an incoming scholars programme. One example is the JSPS Postdoctoral Fellowships[2], which fund international scholars to work in the Japanese research environment.

Proposed action:

- ***Make Rutherford Discovery Fellowships and other similar programmes – open to all. Do not restrict these to permanent residents and citizens. Increase funding of these programmes to attract international talent but without cutting off local talent.***
- ***Increase PhD scholarship funding for international students. Do not specify the areas they can work in; allow them to work on any topic provided a suitable supervisor can be found. This will ensure they can approach the NZ-based researchers in their field for potential supervision.***
- ***Create an incoming postdoctoral fellows' fund for international researchers. This will make New Zealand an attractive place to do research and will provide a mechanism for retaining the best international students trained on our shores as well as attracting scholars trained elsewhere who are looking to begin or continue their research careers here.***

6. Improve funding options for early-career investigator-led grants that include full funding for salary.

My career development has benefitted from New Zealand's early career funding ecosystem, and, more recently, I have had the opportunity to assess investigator-led grant applications from early-career researchers. I see two areas where funding increase will greatly improve the opportunities for attracting, nurturing and retaining the next generation of research leaders.

The Rutherford Discovery Fellowship programme is an excellent scheme. It provides for high quality, investigator-led research across all areas of academic endeavour.
These grants were set up in 2010 and aim to support research at 0.85 FTE for five years. However, there is a tension with such grants because the amount allocated for salary remains well below the cost of funding 0.85 FTE of salary for eligible researchers (between 3-8 years post PhD). The result is that institutions must find the additional funding for the salary of a successful applicant. This gap can lead to compromise scenarios, both of which I am aware have been made through discussions with heads of department:

[2] https://www.jsps.go.jp/english/e-ippan/appliguidelines.html; https://www.royalsociety.org.nz/what-we-do/funds-and-opportunities/catalyst-fund/catalyst-leaders/funding-overview/

First, this can lead in practice to lower fractional FTE available for research; recipients may be asked to perform additional non-research activities because the host institution is in effect paying to top up the person to 1.0 FTE and is subsidising the 0.85 FTE reserved for research.
Second, this gap can make it less attractive to host a recipient as in some instances, an institution is unable or unwilling to meet the additional cost.
As the fraction of the grant that is available for salary has not kept pace with payscale increases, these problems are exacerbated with time.

Another grant mechanism that requires increased investment is the Marsden Fast Start. This award provides funding for investigator-led early-career research. However, a major challenge is that the amount of the award has stayed flat for a number of years, and it is difficult to support salary for recipients. Because these are run similarly to the Marsden Standard applications, salary component is based on salary payscales, in contrast to the Rutherford Discovery Fellowships. However, with a low cap on the size of the award, this creates similar but more acute challenges to those raised above for the Rutherford Discovery Fellowships. It can lead to recipients only working part time as their salary component is only fractionally covered and host institutions may be reluctant or unable to supplement salary.

To make the Marsden Fast Start applications fit for purpose, and to nurture the next generation of researchers, we need to make these awards more attractive, with more stable workplace opportunities. This requires increasing the budget to enable salary to be adequately covered. This needs to be done without a reduction of the total Marsden Fast Start awards. Aligning with point 1 above, the total number of awards needs to be increased to support the top 20% of applicants, including salary at a level required for the research to be undertaken. To avoid the risk of creating part-time scientist postions, 0.8 FTE salary support is recommended.

Proposed action:

- ***For Rutherford Discovery Fellowships, provide full 0.85 FTE salary for successful recipients based on institutional salary payscales (aligning it with how FTE is awarded in e.g. Marsden grants). Do not do this by decreasing total funding available for research; this requires an increase in total award value.***
- ***For Marsden Fast Start grants, increase the award value to enable researchers to cover 0.8 FTE of their salary. Increase the number of awards so that the top 20% of applicants are awarded funding.***

NATIONAL STATEMENT OF SCIENCE INVESTMENT DRAFT
Response from Rutherford Discovery Fellowship recipients (2010-2013)

We thank MBIE and the Minister for the opportunity to comment on plans for future investment in Science.

This is a joint response written and co-signed by 97.5% of New Zealand's Rutherford Discovery Fellows. We are a group of internationally recognised early- to mid-career researchers who have been selected for our innovative approaches to research across the sciences and the humanities. We work in diverse fields, spanning physical, engineering, information and communications technology, medical, molecular and environmental research through to social sciences, law and the humanities. We are based across a wide cross-section of New Zealand's Universities and Crown Research Institutes (CRIs), and are engaged in basic, applied and near-to-market research. All of us have directly benefitted from the investments and changes that the Government has been making to the Science sector. As a result of the Rutherford Discovery Fellowship, we have chosen to return to, or to stay in, New Zealand.

We agree strongly with the Government's message in the draft National Statement of Science Investment (the "Draft Statement"), that greater investment in science is critical for the future prosperity of New Zealand. This document signals a step in the right direction for the future prosperity of our nation.

There are, however, three key issues that we unanimously agree are not adequately addressed in the Draft Statement and require urgent attention:

1. *Funding for science* and research in New Zealand must, as a matter of urgency, be increased until it is comparable to science investment in other small advanced economies (as a fraction of gross domestic product (GDP).

2. Greater expenditure on *investigator-led funding*[a] is required if New Zealand is to develop into a strong and prosperous advanced economy. This must happen in the short term.

3. New Zealand urgently requires *postdoctoral funding* on par with other small advanced economies.

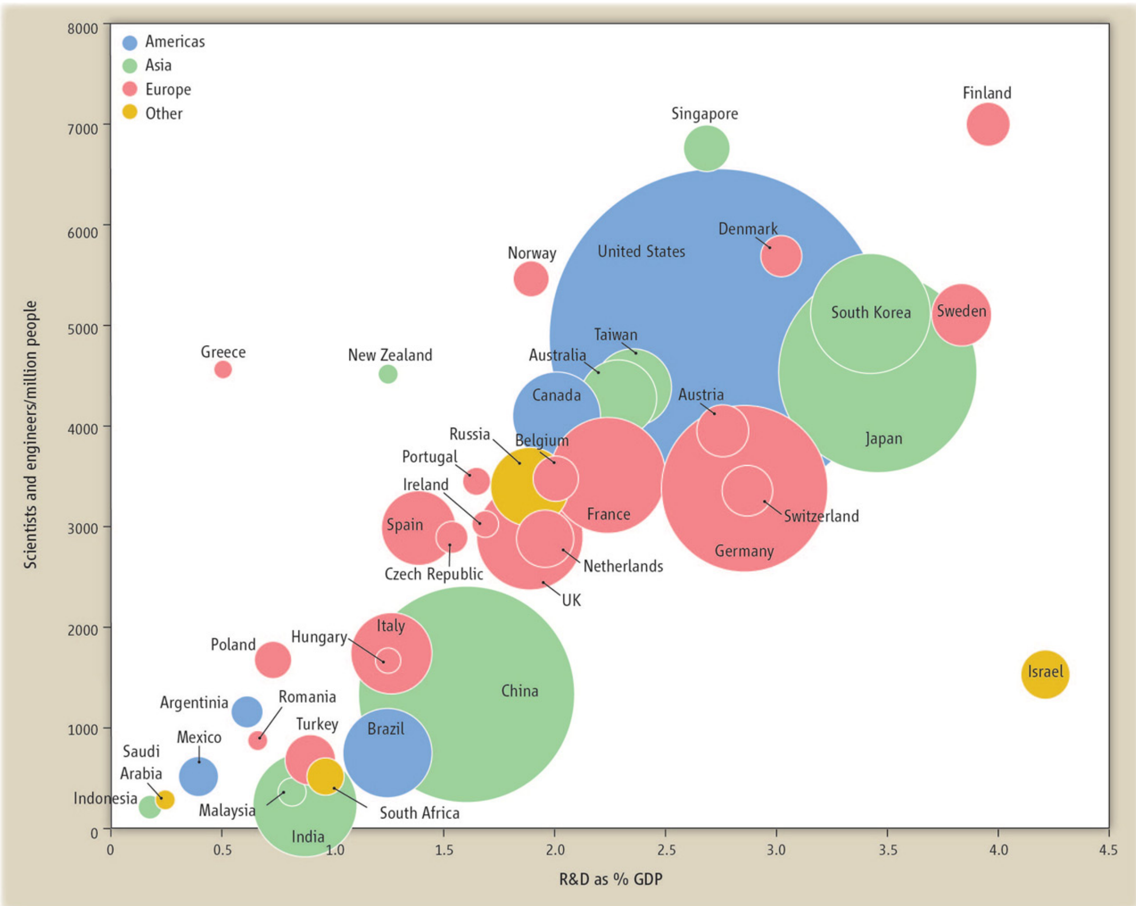
We are pleased that the Draft Statement raises all of these matters, and heartened that some steps have already been taken to address them. However, the benefits of investing in these key areas are not fully articulated in the document. Nor are clear commitments to increasing investment in them made. This is of significant concern – without substantial investment in these key areas, the full economic benefit of a thriving research and innovation sector in New Zealand may never be realised.

[a] Investigator-led science is defined on p12 of the Draft National Statement of Science Investment 2014-2024 as being "undertaken to acquire new knowledge but its direction is suggested by the scientists themselves"

1. **Funding levels need to be comparable to the investments made by other small advanced economies**

The Draft Statement very explicitly acknowledges that, at 0.56% of GDP, our current Government investment in science research and development (R&D) lags behind that of the small advanced economies of Denmark, Singapore, Ireland, Finland and Israel.

We applaud the open manner in which this point is made. However, by comparing ourselves only with these countries, our status as an extreme outlier is obscured. The figure below, published in *Science*, plots the number of scientists and engineers against % GDP for 2011. This shows that we are among the few global anomalies when it comes to R&D investment, and that we would be hard-pressed to convince others of our status as a small advanced economy. We have a comparable number of scientists and engineers to other developed nations, yet we spend far less as a proportion of GDP. With three exceptions, all countries adhere to the strong relationship between number of scientists/engineers and R&D expenditure. Of the other two outliers, Greece and Israel, the Draft Statement clearly signals we do not wish to emulate Greece.



Source: *Press, WH (2013) What's so special about science (and how much should we spend on it?) Science 342:817-822. New Zealand R&D figure includes both Government and Industry sources. Circle size indicates total R&D spending by individual nations.*

The graph makes it clear that we do not have too many scientists and engineers. We simply do not fund them in line with the rest of the world. This may partly explain the statistics in the draft report, which indicate that New Zealand scientists publish at comparable levels to other nations, but our publications tend to have less impact—our scientists have to make do with far fewer resources. Without investment, the greatest risk is that the number and quality of scientists and engineers will decline with time, moving our nation further from its aspirational goals. The risk is that New Zealand will rapidly lose, not attract, top talent.

Recommendation 1

We therefore make an unapologetic call for a substantial and concrete commitment that:

- Government R&D investment will grow to 1.5% of GDP per capita by 2024; and
- Year-to-year funding levels will reflect New Zealand's annual GDP growth.

Increasing R&D expenditure will make New Zealand a far more desirable destination for the internationally mobile science and engineering workforce. We applaud the Government's intention to increase R&D investment to 0.8% but it falls significantly short of what is needed. A commitment of at least 2.5% (combined Government and industry sources) is required if we are to build New Zealand into a small advanced economy. As the Draft Statement recognises, increased future R&D funding will also need to come from the private sector, but that requires initial Government investment to create a healthy science sector. At the moment, there is not even a commitment to increase Government funding to a modest 1% R&D investment rate. Furthermore, the document fails to articulate the primary benefits of increasing investigator-led basic research funding and investing in He Tangata—creating the talented young scientists of the future and retaining internationally competitive mid-career researchers in New Zealand.

2. **Investigator-led funding is critical for developing a strong and prosperous advanced economy.**

We share the Minister's view, that, "High-quality science and innovation can have a transformational effect on a nation" (p. 4 of the Draft Statement). In light of that, we strongly believe that the benefits of contestable, investigator-led funding must be fully recognised. According to the Draft Statement, the primary way in which investigator-led research benefits economies is by creating ill-defined 'knowledge spillovers' (p. 12). But this fails to appreciate the essential role that strong university environments play as *drivers* of successful Innovation Districts.[b]

To be more specific, here are three essential benefits of investigator-led funding that must be recognised as part of future science investment:

A. The capacity to produce the best educational environments

Whether they work in industry, CRIs or universities, New Zealand-trained researchers get their education from the tertiary sector. Advanced postgraduate training teaches people to undertake questions-driven research. In order to be an effective researcher, one must be able to propose new questions, to find innovative new routes to address these questions, and to develop the expertise needed to undertake the research. In short, innovation is the product of

[b] Katz & Wagner, "The Rise of Innovation Districts". Brookings, May 2014, p11 (http://www.brookings.edu/about/programs/metro/innovation-districts).

intellectual freedom. The gap between New Zealand and other small advanced nations in terms of quality of research outputs will widen if basic and basic-applied research environments cannot routinely undertake funded, high-impact international research. These educational environments train the minds that will address the National Science Challenges and find the new scientific applications that will drive the economy, and advance positive social reforms.

B. The reputational and economic benefits from doing international research

To attract and retain the best scientists and postgraduate students, we must respond to the education market. This market is affected by global league tables and New Zealand universities—in contrast to those of other small advanced nations—are slipping down these tables. It is not surprising, then, that New Zealand institutions are attracting fewer and fewer international students.[c] Good investigator-led research in the nation's universities impacts directly on the $2.6 billion education sector by making our institutions more attractive.[d] Conversely, if poor funding leads to declining institutional reputations, the university sector will shrink. This is bad for the education sector and for industry—weaker training of postgraduate researchers would have negative ramifications for industry, applied science, and society. High-impact research (basic or applied) is essential for building New Zealand's credibility as a knowledge and innovation-based economy. Yet, as a nation, we currently fail to adequately support our top researchers.

C. The capacity for new research to lead to new, unimagined applications

In innovative economies, companies are spun out of the best basic research environments.[e] Disruptive innovations emerge from beyond the horizon of what is conceivable in applied or industry-led environments. They require a critical mass of the best and brightest scientists working on the hardest problems. The Draft Statement's aim of improving the ability of applied or industry-led environments to contribute to the economy is good for New Zealand, but this is only part of the picture. Successful research environments overseas strongly rely on basic research to generate new and innovative businesses—that is precisely why innovation hubs are so often linked to universities.[f]

Finally, it is critical for New Zealand to maintain and develop expertise beyond current Government portfolios.[g] This is essential if we are to provide the necessary expert advice and scientific insight to respond rapidly to unexpected challenges, and to translate and apply the results of emerging research conducted elsewhere. This is an important but often under-recognised contribution of fundamental research to Government obligations, and is necessary

[c] Fewer international students are choosing NZ: http://www.educationcounts.govt.nz/publications/tertiary education/145981 Fig. 18, 27.

[d] "The Economic Impact of International Education 2012/13"; the university sector provides the greatest value, at 34.7% of total sector value. http://www.enz.govt.nz/markets-research/general-research/the-economic-impact-of-international-education-2012-13.

[e] "Intellectual eminence" is a key driver of the generation of spin-out companies; Di Gregorio & Shane (2013) "Why do some universities generate more start-ups than others?" Research Policy 32:209-227.

[f] Katz & Wagner, 2014; Henry Etzkowitz, *The Triple Helix: University-Industry-Government Innovation in Action*, Routledge 2008.

[g] Current funding mechanisms are already heavily skewed towards mission- and industry-led science. In contrast, the Marsden Fund represents less than 10% of 'contestable' funds, NSSI Draft p.14.

both for gauging impacts on New Zealand, and to ensure that New Zealand can take advantage of new, unexpected opportunities.

Recommendation 2

If we are to emulate the successes of other advanced small nations, we must make the connection between basic research and innovation. Increasing Marsden funding in 2013 was a step in the right direction but it needs to continue. The Marsden Fund is the main sponsor for investigator-led basic research in New Zealand. It is well conceived but woefully under-funded—current success rates are below 10%.[h] With few funding alternatives, many first rate research projects (i.e. in the top 20% of applicants) are left unfunded, time that could have been spent on research is lost to futile grant-writing,[i] or, worse still, the research is carried out overseas and our intellectual property is lost offshore. We propose that future strategic investment includes a commitment to turn the Marsden Fund into a powerful generator of innovation. We would like to see application success rates rise to 20%, in line with other, similar funds overseas.[j] At 2013 levels, this would entail an increase to $152.2 million.[k]

3. New Zealand urgently requires postdoctoral funding on par with other small advanced economies

We are pleased that there is some dedicated Government funding for postdoctoral fellows through the Rutherford Foundation Trust. However, this is extremely limited (it currently funds only five positions per year) which creates major problems surrounding the opportunities for postdoctoral research in New Zealand. There is widespread agreement that there are too few opportunities for postdoctoral scientists in New Zealand. We wish to highlight two major problems that result.

A. New Zealanders and New Zealand-trained foreign PhD students are pushed overseas at the most productive point in their careers

The effect of the severe bottleneck at the postdoctoral stage in the careers of young scientists is that we are inadvertently creating ***a place where talent has to leave.*** Given the outward-looking nature of many New Zealanders, a period spent overseas can be valuable. However this is not universally true. For many PhD graduates from cutting-edge research groups, it makes better sense to stay in New Zealand and consolidate their skills. If they do this, they contribute to the New Zealand research environment just as they become most useful.

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[h] Last year, 40 of 330 Fast Start applications were funded (12.1%), and 69 of 827 Standard applications (8.3%). Increasing success rates to 20% across the board would mean funding 66 Fast Starts and 165 Standards.

[i] The reduction of successfully funded NIH grants in the US from 30% to 16.8% (http://nexus.od.nih.gov/all/2014/01/10/fy2013-by-the-numbers/) has been linked to the damaging effects of hypercompetition by Alberts et al. (2014) Rescuing US biomedical research from its systemic flaws. PNAS 111:5773-6; a recent calculation of the time spent in 2012 in Australia on grant writing indicates that, with success rates of 20.5%, the equivalent of four centuries of effort was lost (Herbert et al. 2013 “Funding: Australia’s grant system wastes time”. Nature 495: 314).

[j] Success rates for Australian Research Council Discovery grants are on the order of 20% (http://arc.gov.au/ncgp/dp/dp_outcomes.htm).

[k] Average Marsden Fast-Start grant in 2013 was $345,000 (including GST). The average Standard grant in 2013 was $782,754 (incl. GST). Therefore, total funding required to lift success rates to 20%, based on 2013 numbers, is **$152.2M** (incl. GST).

For New Zealand-trained foreign scientists looking to stay, or for international PhDs looking to settle, the dearth of postdoctoral funding for domestic or incoming scientists is a major problem. Postdoctoral research often coincides with other major personal milestones like getting married and starting a family. This makes it more likely that talented New Zealand and New Zealand-trained postdocs will settle offshore, particularly if they remember a NZ science system that fails to support top researchers. Failure to address this issue is a major shortcoming of the current Draft Statement.

B. New Zealand research teams are overly reliant on postgraduate students

Lack of dedicated postdoctoral funding also means that most New Zealand research teams, which are small, investigator-led teams, suffer acutely from talent loss. Because few students are able to secure funding for postdoctoral research, New Zealand scientists have to run research groups with scientists-in-training. It is routine for labs in other parts of the world to have one or two experienced postdoctoral scientists playing a senior role in driving research and providing coalface expertise to postgraduate students. Strong postdoctoral support is therefore essential for building research depth, allowing New Zealand science environments to capitalise on that depth, and creating an ecosystem where established early-career scientists can begin to drive their own research and develop their career, be it academic, applied or translational.

It should also be noted that although the impact of the postdoctoral funding void is most keenly felt in academic and applied science, it also impacts on industry. Scientists with five to six years of advanced training are better placed than recent PhD graduates to recognise opportunities to develop and spin-out advanced technologies.

Finally, the postdoctoral period is the 'make-or-break' time in a researcher's career. As a result, postdoctoral students are usually highly productive and hardworking. Savvy institutions can capitalise on this to increase their productivity. The fact that many science environments overseas are reducing their investment creates a real opportunity for New Zealand to recruit top international and expatriate postdoctoral scientists to our shores.

Recommendation 3

Government funding for postdocs should be radically increased. We believe that an increase from the current five (funded by the Rutherford Trust) to 100+ new postdocs (0-5 years post-PhD) per annum would transform research quality, depth and diversity in the way the Minister desires. It would bring NZ into line with the nearly 400 postdoctoral fellowships available in Australia for researchers at this early career stage[i] and provide a competitive foil to the tendency for young, productive researchers to leave New Zealand and never return.

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[i] Through the Discovery Early Career Researcher Awards, 200 postdoctoral positions are available annually (0-5 years post PhD) (http://arc.gov.au/ncgp/decra.htm), and similar numbers of fellowships are available through National Health and Medical Research Council (http://www.nhmrc.gov.au/grants/outcomes-funding-rounds)

Rutherford Fellowship scheme

Finally, we think it is appropriate and timely to provide feedback on the Rutherford Discovery Fellowship scheme, from which we are all benefitting. The initial scheme, as run in 2010 and 2011, was a fantastic initiative as it provided a strong incentive for talented New Zealand scientists to stay in or return to New Zealand. It also provided employment stability. While we appreciate that external pressures necessitated an early review, we are not convinced the majority of changes that have emerged from the prematurely initiated review process are helpful for early- to mid-career scientists, nor for the science sector of New Zealand. We agree that the original tier system was not necessary, and we welcome the decision to allow both citizens and permanent residents to apply. However, we question the decision to allow hosts not to employ Fellows at the end of their Fellowship. This creates instability and uncertainty, may deter future overseas applicants from relocating, and risks recipients being forced to leave New Zealand at the end of their contracts. We therefore favour the introduction of a clear tenure-track requirement as part of the revised scheme. Leading research providers in other advanced economies, including Sweden's Karolinska Institutet, Denmark's University of Copenhagen and the University of Helsinki in Finland[m], are now providing clear guidelines for tenure, modelled on the tenure-track system in the US. Given the potential for the RDF scheme to be of value to tertiary providers, CRIs and the development of science that could create spin-out companies, we favour evolution of the scheme towards a tenure-track model with a clear path for successful Fellows to transition to tenured academic or employed staff scientist positions. Currently there is no clear pathway, even for those scientists who have been identified as New Zealand's future research leaders.

Summary

It is our strong belief that a national research funding pipeline that provides for early to mid-career development of New Zealand-based scientists and researchers is critical to the goals laid out in the National Statement of Science Investment document. There is an urgent need for a coherent career funding programme that provides opportunities throughout the career development of young researchers which can fully support internationally competitive research groups based in New Zealand. To achieve this, there must be substantial support for both junior postdoctoral researchers and early-mid career researchers (senior postdoctoral fellows) to pave the way from PhD research into permanent positions as lecturers/professors/staff scientists working in CRIs and industry. Such a funding pipeline requires three key components:

1. A substantial postdoctoral fellowship scheme, with dedicated funding for 100+ new postdocs each year, covering 0-5 years post-PhD.

2. A tenure-track Rutherford Discovery Fellowship, funding 10-25 new 5-year fellows each year, covering 3-10 years post-PhD.

3. An increase in investigator-led basic research funding, enabling the top 20% of Marsden applications to be funded.

[m] Wald, "Structuring Academic Careers in Europe". Science Careers, May 2008 (doi: 10.1126/science.caredit.a0800063); http://www.helsinki.fi/recruitment/tenuretrack.html; http://employment.ku.dk/tenure-track/tenure-track-at-ucph/

We welcome the opportunity to discuss these and other aspects of the Science ecosystem with the Minister and representatives from the Ministry. We will hold our annual workshop on 27th November 2014, and we cordially invite both the Minister and MBIE to meet with us during our workshop. Alternatively, one or two of our number could meet with officials to discuss the suggestions in this document.

Once again, we applaud the Government's efforts to engage in the building of a small advanced economy, and we sincerely believe that we can help create the conditions Sir Paul Callaghan aspired to build, namely: 'a place where talent wants to live'.

Signed,

Rutherford Discovery Fellowship Awardees 2010-2013

Full list of signatories:

1. Associate Professor Donna Rose Addis, The University of Auckland, RDF 2010.
2. Dr. Martin Allen, University of Canterbury, RDF 2012.
3. Dr. Barbara Anderson, Landcare Research, Dunedin, RDF 2012.
4. Associate Professor Quentin D. Atkinson, The University of Auckland, RDF 2011.
5. Associate Professor Nancy Bertler, Victoria University of Wellington, and GNS Science, RDF 2011.
6. Dr. Ashton Bradley, University of Otago, RDF 2010.
7. Dr. Brendon Bradley, University of Canterbury, RDF 2013.
8. Associate Professor Murray P. Cox, Massey University, RDF 2010.
9. Professor Alexei Drummond, The University of Auckland, RDF 2010.
10. Dr. Peter Fineran, University of Otago, RDF 2011.
11. Dr. Paul Gardner, University of Canterbury, RDF 2010.
12. Dr. David Goldstone, The University of Auckland, RDF 2011.
13. Associate Professor Noam Greenberg, Victoria University of Wellington, RDF 2010.
14. Professor Jennifer Hay, University of Canterbury, RDF 2010.
15. Dr. Justin Hodgkiss, Victoria University of Wellington, RDF 2011.
16. Dr. Jessie Jacobsen, University of Auckland, RDF 2012.
17. Associate Professor Eric Le Ru, Victoria University of Wellington, RDF 2010.
18. Dr. Peter Mace, University of Otago, RDF 2012.
19. Dr. Dillon Mayhew, Victoria University of Wellington, RDF 2013.
20. Dr Rob McKay, Victoria University of Wellington, RDF 2013.
21. Dr. Clemency Montelle, University of Canterbury, RDF 2012.
22. Associate Professor Nicole Moreham, Victoria University of Wellington, RDF 2011.
23. Dr. Suresh Muthukumaraswamy, The University of Auckland, RDF 2013.
24. Associate Professor Shinichi Nakagawa, University of Otago, RDF 2012.
25. Dr. Suetonia Palmer, University of Otago Christchurch, RDF 2013.
26. Dr. Wayne M. Patrick, University of Otago, RDF 2011.
27. Associate Professor Anthony M. Poole, University of Canterbury, RDF 2011.
28. Dr. Craig Radford, The University of Auckland, RDF 2013.
29. Dr. Nicholas J. Rattenbury, The University of Auckland, RDF 2012.
30. Associate Professor John N.J. Reynolds, University of Otago, RDF 2010.
31. Dr. Nicholas Shears, The University of Auckland, RDF 2011.
32. Dr. Lara Shepherd, Te Papa Tongarewa, RDF 2012.
33. Dr. Jonathan Sperry, The University of Auckland, RDF 2013.
34. Dr. Elizabeth Stanley, Victoria University of Wellington, RDF 2013.
35. Dr. Daniel B. Stouffer, University of Canterbury, RDF 2013.
36. Professor Jason M. Tylianakis, University of Canterbury, and Imperial College London, RDF 2010.
37. Dr. Angela Wanhalla, University of Otago, RDF 2013.
38. Dr. Geoff Willmott, The University of Auckland, RDF 2012.
39. Dr. Tim Woodfield, University of Otago Christchurch, RDF 2012.

Japan's path to becoming leaders in 'Western' Science: an Asian perspective on science and other forms of knowledge.

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Here in Aotearoa New Zealand, there are a range of well-intentioned efforts to incorporate Mātauranga Māori into science. These include a pilot programme in NCEA science subjects, such as biology & chemistry, where the aspiration is to incorporate concepts from mātauranga Māori on an equal footing with science[1]. Likewise, there are efforts to incorporate mātauranga Māori into the science curricula at some universities, and perhaps even to incorporate it into science-policy discussions[2]. In this article, I wish to contribute an Asian scientific perspective on this discussion.

Why do we need an Asian perspective? At the 2018 census, the diverse Asian diaspora of New Zealand made up 15.1% of the population, with about a quarter of Asians under 19, and thus of school age[3]. Education matters to Asians as much as to other ethnicities, so conversations on national curriculum changes should include us. To that end, I believe we have a helpful perspective to offer on the current conversation. As a part-Japanese New Zealander, I offer mine in good faith: the science and education systems are relevant to us all.

First, some statistics. Universities in Asia are emerging as among the world's best places to do science. One can get an idea of this by looking at the 2021 QS World University Rankings. In Engineering & Technology, eight of 25 of the top ranked universities are in Asia[4]. For subjects central to our NCEA science curriculum, Asian universities are in the mix: 2/25 in Biological Sciences[5], 5/25 in Physics & Astronomy[6], with an impressive nine Asian universities in the top 25 for Chemistry[7]. The countries represented include Singapore, China, Japan and Korea. The remainder of the lists are made up of US and European institutions. Australian and New Zealand universities are all outside the top 25 for these subjects. While one can quibble about the value of such rankings, it is clear that Asian countries are now among the very best in the world when it comes to science. While science practiced in the West has made major advances, as these statistics show, it is now global in nature and in reach. Clearly, we have come a long way.

How long a way? One side of my heritage stems from one of the most insular countries of the past 500 years, and I want to share part of the story of how we went from isolationism to scientific powerhouse. My culture has concepts that are very similar to many of those in mātauranga Māori that are being considered as part of the pilot NCEA science curriculum:

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[1] https://ncea.education.govt.nz/science/chemistry-and-biology
[2] http://www.maramatanga.co.nz/publication/te-p-tahitanga-tiriti-led-science-policy-approach-aotearoa-new-zealand
[3] https://www.stats.govt.nz/tools/2018-census-ethnic-group-summaries/asian
[4] https://www.topuniversities.com/university-rankings/university-subject-rankings/2021/engineering-technology
[5] https://www.topuniversities.com/university-rankings/university-subject-rankings/2021/biological-sciences
[6] https://www.topuniversities.com/university-rankings/university-subject-rankings/2021/physics-astronomy
[7] https://www.topuniversities.com/university-rankings/university-subject-rankings/2021/chemistry

concepts like whakapapa, mauri, and kaitiakitanga are familiar to us. Our traditional culture and religion is polytheistic and animistic, and we have prized traditional knowledge that has now found currency globally. Yet, in recent years our scientists have won Nobel prizes for the invention of blue-light LEDs[8] (think smart phone screens) and lithium-ion batteries[9] (think electric vehicles).

That formerly insular country is Japan, and the origins of modern science was not so much 'Western' as Dutch. I first want to relay a famous episode[10] that encapsulates the development of modern science in Japan, and then I will return to the question of how our traditional thinking sits alongside modern science.

We start our journey in 1771 in Edo (modern-day Tokyo) at Kotsugahara (the 'Plain of Bones'), and the execution of a convicted murderer. Several physicians, including Sugita Genpaku, went to witness the executioner dissecting the body, as was the custom in those days. Their interest in such a gruesome event was to compare knowledge from two cultures. They took with them a traditional Japanese text on anatomy derived from Chinese teachings, and a Dutch book called '*Ontleedkundige Tafelen*', itself a translation from a book originally published in German.

The significance of this is that, at this time, and until the Americans forced Japan to open her borders in 1853, Japan was a closed country. The only westerners allowed into Japan were the Dutch, but even they were barely allowed to enter: The Dutch East India Company was allowed to trade, but were restricted to the island of Dejima, outside of Nagasaki. It was only from 1720 that foreign books were allowed into the country.

At the execution, what Sugita and his colleagues found was that the illustrations in the Dutch text were the more accurate by far, and they resolved there and then to translate it into Japanese. The resulting book, *Kaitai Shinsho* (A New Book on Anatomy), was published in 1774. It became the standard text on anatomy, displacing the earlier texts derived from Chinese knowledge. In doing so, Sugita and colleagues actively overturned the orthodoxy of the time, where physicians would keep their knowledge secret, teaching it only to their disciples. This endeavour is remembered in a memorial in Tokyo, with an inscription that reads,

'*the source of rangaku (Dutch studies) sprang from here and served to revitalise the progress of modern Japanese science*'.

Japanese recognise the importance of the painstaking work that Sugita and his collaborators undertook in bringing 'western' scientific knowledge into its own sphere.

This episode indicates several of the most wonderful things about science. First, it can and should be shared, for the betterment of humanity. Second, it shows that any concept can be translated into any language. This is of course not trivial: Sugita documented the arduous

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[8] https://www.nobelprize.org/prizes/physics/2014/press-release/
[9] https://www.nobelprize.org/prizes/chemistry/2019/press-release/
[10] Sakula (1985) Kaitai Shinsho: the historic Japanese translation of a Dutch anatomical text. Journal of the Royal Society of Medicine 78:582-587.

challenge that he and his coauthors faced in his book, '*Rangaku Koto Hajime*' (The Beginning of Dutch Learning). This included needing to understand Dutch words that did not have a Japanese equivalent, and create those equivalents. Sugita's own words best sum up the scientific mindset, when confronted with new knowledge:

"*On our way home, [we] talked about the strong impression this made on us. We were ashamed of having lived so far in such a complete ignorance and served our lords day after day as physicians without the slightest idea of the true configuration of the body, whereas this should have been considered the foundation of our art*".

Sugita is known for another episode where he found he was wrong about a contemporary's work in obstetrics. Kagawa Gen'etsu's work *Sanron*, published in 1765, described his observation that a developing foetus is positioned head-down in the mother's womb. Sugita expressed skepticism in *Kaitai Shinsho* of this theory, which was not documented in the Dutch texts, and was not known from traditional theory. He later discovered that Kagawa's observations were in fact correct, and openly admitted his error. This is another wonderful thing about science. Unfortunately not all scientists are as honourable as Sugita, but over time this process means it tends to correct errors and zero in on the truth.

So how has Japan reconciled traditional thinking and modern thinking? Did it develop a different form of science? This question was raised by one of our greatest writers, Tanizaki Junichiro, in a wonderful essay, *In'ei Raisan* (In Praise of Shadows, 1933), in which he criticises modern gaudiness and praises Japanese aesthetics, which favour darkness and shadow, inviting mysticism and imagination.

He muses,
"*Suppose for instance that we had developed our own physics and chemistry: would not the techniques and industries based on them have taken a different form, would not our myriads of everyday gadgets, our medicines, the products of our industrial art – would they not have suited our national temper better than they do? In fact our conception of physics itself, and even the principles of chemistry, would probably differ from that of Westerners; and the facts we are now taught concerning the nature and function of light, electricity, and atoms might well have presented themselves in different form.*"

The answer from each and every instance of adoption of science across Asia, including in Japan itself, is a resounding no. Physics and chemistry are not social or aesthetic constructs; they are concerned with phenomena that exist even if our species does not. To his credit, Tanizaki, who was known to have a penchant for irony, goes on to say,

"*Of course I am only indulging in idle speculation; of scientific matters I know nothing.*"

But his question is worth exploring a little further, not least because of the similarities in our traditional thinking and Māori traditional knowledge. Let me tell you about a few examples that I hope shed some light on how our cultural and scientific worlds interact, but where it is also clear that they give each other space.

The first example is a wonderful little monument to microbiology at *Manshu-in Monzeki*, a temple in Kyoto. On the grounds is *kinzuka* ('microbe mound'), which carries an inscription by Sakaguchi Kinichiro, who invented the Sakaguchi flask used for microbial culturing. The inscription reads,

To the innumerable souls of microbes
Who have dedicated and sacrificed
For the existence of humans,
We pay our deepest respect.
Here we hold a memorial service
For their soul's rest and condolence,
Building a microbe mound.

My collaborators in Kyoto took me to *Manshu-in*, and I was told that all the members of the lab are expected to visit it. This offers a moment of calm and an opportunity for reflection, and is something quite unique to Japan. As an aside, when we first set up our collaboration, we also went to pray for the success of the collaboration. This resulted in a somewhat comical exchange between the lab head and one of the postdocs: the postdoc on the project refused to pray at a Buddhist temple as he is Christian! However, what is important about this story is that, by contrast, stepping inside the laboratory, one could be anywhere in the world: the methods are clearly described and standard, the equipment recognisable. And when we swap protocols, they can be—and indeed are—readily applied in either lab, albeit with a little translation required at times!

Japanese culture is unique, important, and has protocol and etiquette, but it is separate from the details of how to grow microbes or how to extract DNA from them; these things are independent of human culture.

That said, Japanese research environments often hold history as important. The microbiology lab that I am currently collaborating with has a very long history, being established in the 15th year of the Taisho era (1926). Thus, the current head, Professor Ogawa Jun, is the latest in a line of lab heads. He has on his office wall photographs of his predecessors. I can well imagine these pictures invoke a mix of emotions: one must feel pride, a weight of expectation, not to mention humility.

Some areas of their research are informed by local interest and traditional arts. One particularly interesting case for me was learning about the mechanistic basis of *Aizome* (traditional indigo dyeing). The process of *Aizome* involves extracting indigo dye by a long ~100 day oxidative fermentation of the leaves of the Japanese indigo plant, then microbial reduction under alkaline conditions, yielding leuco-indigo, which is then able to be used for dyeing cloth. The traditional process is fascinating in itself, and no artisan needs a scientist's insights to improve their craft. However, the scientific part is understanding precisely how it is that the extraction process works. And what science can offer from that knowledge is astonishing. My colleagues have taken this well beyond just the study of how a traditional process works: they have built on this knowledge and constructed a microbial fuel cell from it[11]. That is mind-blowing, and something only science can do.

I have touched on religion, but I want to end by diving straight in the deep end. There are times where science has come into conflict with other parts of human knowledge. For instance, Japanese are familar with the stories in the *Kojiki* (A Record of Ancient Matters), our oldest written text, dating to 711CE. It describes the genealogy of the Imperial family, and provides written accounts of oral tradition, stories, mythology and our *kami* (gods). It includes the claim that the Emperor's genealogy is divine – tracing back to *Amaterasu*, the Sun Goddess, and it details the creation stories of the Japanese archipelago. As a scientist, I understand that, if held up to the light of modern genetics, linguistics, or geology, these stories, if taken literally, are absolute nonsense. The science-informed views of the origins of the Japanese people and the lands they inhabit have superceded these as they are are based in fact. But that does not detract from the central place of these stories in Japanese culture, history and heritage. They are treasures, and they should not be conflated with science.

I can think of no better embodiment of how our national religion, *Shinto*, sits alongside science than to tell you a little about Emperor Akihito, who abdicated in 2019, ending the *Heisei* era, with his son's ascent to the throne marking the beginning of the *Reiwa* era. Ancient texts are consulted in choosing an appropriate name for the new era. Being the head of our indigenous religion that states he descends from the Sun Goddess, it is remarkable to learn that Emperor Akihito is a keen ichthyologist (fish biologist), who has published numerous papers, in both Japanese and English-language scientific journals. In an article from the journal *Science*[12], where he discusses the early development of science in Japan, he writes,

"*Since science pursues truth and scientific methodology puts truth to the use of mankind, it is desirable that such studies be pursued through cooperation that transcends national and other boundaries.*"

It is worth reminding oneself that Emperor Akihito was a child when Tokyo was firebombed, when two atomic bombs were dropped on Japan, and when his father, Emperor Hirohito, was forced to recant his status as *akitsumigami* (a god in manifestation). It is also worth noting that Hirohito himself was also a marine biologist, having published on hydrozoans (small marine animals), and even had a marine biology laboratory at the Imperial Palace! Both have boycotted the *Yasukuni* shrine where war criminals have been buried, and both espouse science, despite each having been head of a religion that places them as gods among men.

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[11] Kikuchi et al. (2021) Indigo-Mediated Semi-Microbial Biofuel Cell Using an Indigo-Dye Fermenting Suspension. Catalysts 11(9):1080. doi.org/10.3390/catal11091080

[12] Akihito (1992) Early cultivators of science in Japan. Science 258:578-580.

This to me is the embodiment of what Stephen Jay Gould called non-overlapping magisteria, which he coined in response to Pope John Paul II stating, in a document called, 'Truth Cannot Contradict Truth' on the Catholic Church agreeing that the theory of evolution and Catholic doctrine on the soul entering the body were both correct. Gould argued that religion and science are non-overlapping, one dealing with facts and theories, the other with moral meaning and value, but they do nevertheless "*bump right up against each other, interdigitating in wondrously complex ways along their joint border*"[13].

I think that this is worth considering in national discussions of the interface between Mātauranga Māori and science, and which parts of mātauranga belong in science teaching versus other subjects. Some parts are problematic to include in science, such as arguing for mauri in the vitalistic sense (that there is an identifiable life force), but we can of course understand the values inherent in such a term. This is true in Japanese, where the equivalent to mauri is, *ki*, a word that is peppered through everyday language. For instance, when we say '*ki o tsukete'* (take care) the literal translation would be *switch on your mauri*! In as much as the Japanese Imperial family descend from *kami* and Māori whakapapa to *atua*, these ideas fall outside of science. *Kami* don't figure in the marine biological studies of our two past Emperors, despite their own supposed genealogical descent from *kami*. Japanese traditional aesthetics, as Tanizaki praises, finds beauty in shadows and what ghosts might be hidden there, but there is also beauty in what Richard Dawkins called 'Unweaving the Rainbow', and the illumination that science sheds on the world. They occupy different magisteria.

This point is well understood by some of the most eminent Māori thinkers. Here for example is Sir Mason Durie's take[14] on the relationship:

"*You can't understand science through the tools of Mātauranga Māori, and you can't understand Mātauranga Māori through the tools of science. They're different bodies of knowledge, and if you try to see one through the eyes of the other you mess up.*"

We need to explore the interdigitating border between Mātauranga Māori and science. Some parts of the former may be compatible with the latter (as with the *Aizome*-inspired microbial fuel cell!), while others might be better dealt with through the lens of non-overlapping magisteria. Those who wish to overlap these too uncritically would do well to remember the legacy of the criminal executed on the Plain of Bones; their fate sealed the fate of much of traditional Japanese medicine.

[13] Gould (1997) Non overlapping magisteria. Natural History 106: 16-22.
[14] Rauika Māngai. (2020). A Guide to Vision Mātauranga: Lessons from Māori Voices in the New Zealand Science Sector.