New Zealand Science Review

Vol 76 (4) 2020

The Neutral Theory of Evolution

Renewing the science system

One Health Aotearoa

Official Journal of the New Zealand Association of Scientists

ISSN 0028-8667

New Zealand Science Review

Vol 76(4) 2020

Official Journal of the New Zealand Association of Scientists
P O Box 1874, Wellington
www.scientists.org.nz

A forum for the exchange of views on science and science policy

Editor: Allen Petrey
Production Editor: Geoff Gregory

Contents

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Instructions to Authors

New Zealand Science Review provides a forum for the discussion of science policy. It also covers science education, science planning, and freedom of information. It is aimed at scientists, decision makers, and the interested public. Readability and absence of jargon are essential.

Manuscripts on the above topics are welcome, and should be emailed to the editor (editor@scientists.org.nz).

As well as full papers, short contributions, reports on new developments and conferences, and reviews of books, all in the general areas of interest detailed above, are invited. The journal may also accept reviews of a general nature and research reports.

Full manuscripts (with author's name removed) will be sent for peer review, and authors will be sent copies of the reviewer's comments and a decision on publication. Manuscripts should not normally have appeared in print elsewhere, but already published results discussed in the different, special context of the journal will be considered.

Manuscripts should be accompanied by biographies of not more than 100 words on each author's personal history and current interests. Authors are also expected to supply a suitable high-definition passport-size photograph of themselves. This will be published with the article.

Articles may be submitted in MS Office Word, rich text format, or plain text. Diagrams and photographs should be on separate files (preferably eps, tif, jpg, at 300 dpi), not embedded in the text.

All tables and illustrations should be numbered separately – Tables 1, 2, 3, 4, etc., and Figures 1, 2, 3, 4, etc. – and be referred to in the text. Footnotes should be eliminated as far as possible. Diagrams and photographs will be printed in black and white, so symbols should be readily distinguishable without colour, and hatching should be used rather than block shading. However, colour may be used if the author or the author's institute is willing to pay for the added cost.

References should preferably be cited by the author–date (Harvard) system as described in the Lincoln University Press *Write Edit Print: Style Manual for Aotearoa New Zealand* (1997), which is also used as the standard for other editorial conventions. This system entails citing each author's surname and the year of publication in the text and an alphabetical listing of all authors cited at the end. Alternative systems may be acceptable provided that they are used accurately and consistently.

In this issue

This issue has a range of articles, public statements, abstracts and news items. In our first article, Geoff Chambers presents a historical review of the debates over the mechanisms underlying evolution that raged in the 1970s. He outlines how the challenges to Darwin's hypothesis of natural selection were resolved by the 'Modern Synthesis' entailing single-gene models that explained how mutations could remain in populations even when they were deleterious. Kimura's 'Neutral Theory', which recognised that mutations have low non-directional selection coefficients, can accommodate modern findings of 'rampant genetic variation at the molecular (DNA) level' and now 'serves us best as an excellent null hypothesis'.

New Zealand banknote promotes rugby is the provocative title of John Campbell's article about a young man grafting away in the forwards, who learned to play at Nelson College and Canterbury College and twice played on Christchurch's hallowed turf at the late Lancaster Park. The young man was Ernest Rutherford and the banknote the New Zealand one hundred dollar note.

Rutherford's rugby career was undistinguished but as John points out it was an example of what we are in danger of losing in this professional era: grass roots rugby is played not for financial reward but for comradery, enjoyment, and team spirit. John's account also provides insights into Rutherford's persistence coupled with luck in the pursuit of a research scholarship that allowed him to grow his science career at Cambridge University.

The paper by Sarah Harrison *et al.*, *One Health Aotearoa: a transdisciplinary initiative to improve human, animal and environmental health in New Zealand,* draws our attention to the increasing recognition that complex health challenges at the human-animal-environmental interface require a transdisciplinary, 'whole-of-society' approach.

One Health Aotearoa brings together and facilitates interactions between people from diverse disciplines, links to stakeholders and communities, and engages with policy-makers, government operational agencies, and funders, thus providing a holistic and integrative systems-thinking approach to address priority questions and achieve desired comprehensive outcomes.

Also in this issue, we have two Public Statements. The first, *Renewing the Aotearoa New Zealand Science System,* calling for a connected, evidence-based, adequately funded research ecosystem, is a plea from the Association for a wide-ranging review – with teeth. Socioeconomic pressures from Covid-19 and the climate emergency suggest globally and nationally we are at a crossroad. The motivations for rethinking and reorganising the science system are outlined – its purpose and structure – to give us the information and tools to take the best path possible for the challenges ahead.

The second is the call from the presidents of seven New Zealand scientific associations for Ministerial intervention in Massey University's science cuts.

This October 2020 call is in the form of an open letter to Massey University's Executive and the Ministers of Tertiary Education and Research, Science and Innovation[1] and says the sheer magnitude of proposed change, its lack of clear definition, and intended purpose stand in stark contrast to the legislative definition of a university.

Association president, Prof Troy Baisden takes the discussion of Massey's proposals further in his President's Column.

Finally in this issue we carry the abstract of 'Glass ceilings in New Zealand universities: Inequities in Māori and Pacific promotions and earnings' by Tara G McAllister *et al.,* and then, as news items, Vladimir Šucha's and Marta Sienkiewicz's 'Science for Policy Handbook', The International Science Council and the United Nations' technical report on hazard definition & classification, and the University of Auckland's Faculty of Education and Social Work's report on state of creativity in New Zealand schools.

Allen Petrey
Editor

[1] See http://bit.ly/MasseyCuts

President's column

This President's Column serves as an updated version of my address to our November 2020 Annual General Meeting. Like many other aspects of 2020, the President's address would have been disrupted and out-of-date quickly, so I hope you find my words below timely, and also a good summary.

I was elected to the Presidency at our 2019 Conference, which focused on the deep issues of equity and diversity in science. This formed a theme for the year, with multiple publications helping to provide evidence for the potential severity of Covid-19 impacts on diversity in science. First, Ann Brower and Alex James quantified the wage gap between female academics and their male counterparts, over a career, and showed that without intervention this gap would continue. Furthermore, Tara McCallister, Sereana Naepi and others have published a string of papers quantifying how underrepresented Māori and Pasifika are in research, and specifically in science.

This emerging work, and the consensus from our conference, provided weight to argue strongly for measures from funding agencies and institutions to mitigate the expected impacts of the pandemic on diversity and equity in the science workforce. The initial response was a mixed bag, with a top-up of existing MBIE programmes as the simplest way to keep money flowing into the research system, but a cancellation of the Smart Ideas prior to the full proposal stage was seen as a significant blow to innovative new science and younger researchers. Only in recent weeks has the main thing we've called for finally got underway – a new national post-doctoral fellowship scheme. This is the first since the long-standing post-doc scheme was cancelled in 2010, as a result of what then-NZAS President Shaun Hendy eventually identified as a maths mistake by the Ministry. The new scheme is initially funded as a one-off, so we will lobby hard for it to continue and for an assessment of whether it should be enlarged, perhaps to 50 fellows per year rather than the current 30.

This year's most frustrating issue by far has been Massey University's plan to cut about one-third of its science staffing, including much of the excellence in fundamental sciences that founded the Albany campus in Auckland's fast-growing north. While some consolidation could be understood, claims that teaching of nearly all previous subjects can be continued digitally must be questioned. Worse, changes to the finances and expectations of academics appear incompatible with committing senior staff national and international research leadership, and Massey has silenced its academics from commenting publicly. Our members are deeply concerned, and I welcome contact[1] from any who haven't been in touch. So far, NZAS has led an open letter to the Ministers of Tertiary Education and Research, Science and Innovation from the presidents and past-presidents of a number of New Zealand's learned societies, suggesting that Massey's actions are inconsistent with all aspects of the definition of universities in the Education Act, with particular concerns about research[2].

Our letter requested intervention, not directly from the Minister, but by installing an independent mechanism of oversight and review to ensure consistency with the legislation. The Minister has made clear that the views are appreciated, and the solution was potentially elegant, but after legal review apparently not feasible under the Act due to the mechanisms maintaining the independence of Universities. Massey continues on its course, though perhaps more slowly and carefully than otherwise would have occurred. We stand by to debate every step in the media, and to seek accountability through the Official Information Act and other mechanisms so much as we are able. The biggest concern, looking across the ditch to Australian Universities, including Murdoch and Southern Cross that have enacted similar schemes, is wider application of the same goals and tactics to the detriment of science excellence and great uncertainty for scientists.

Focusing on a wide issue where we can be proactive, Council plans to continue making the case for improvements to the sustainability of science careers in New Zealand. The pandemic's challenges force us to think hard and make action more urgent. The problems are threefold and start with steps toward workable early career progression within New Zealand rather than a dependence on sending talent overseas and recruiting talent to these shores. Following immediately on that is the need to address diversity and equity imbalances, starting simply with the ability of scientists to also remain connected with family, whanau and place-based research. The last is a broader issue we will also focus on – the need to rebalance the science system to support capability directly in the form of people, equipment, laboratories and institutions. Our system remains internationally unique in being so dependent on 'turning the crank' to deliver research outputs. A number of reports and analyses, including our own, point out the once-in-a-lifetime opportunity for a reset.

I will close with a brief thank you to all on Council for their continued efforts and note the following special efforts. The *New Zealand Science Review* and its guest editors have produced two remarkable special issues on Mātauranga and Science; Georgia Carson has led an effort to develop NZAS as a hub of Early Career Researcher networking and engagement; and congratulations to former President and continuing Councillor Shaun Hendy on being named a Member of the New Zealand Order of Merit for services to science.

Troy Baisden
President

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[2] See p. 112.

The Neutral Theory of Evolution

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Introduction

Today most people are perfectly happy to accept Charles Darwin's ideas about '*evolution by means of natural selection*' as the dominant paradigm in biology. So many of us may be quite surprised to know that this has not always been the case among professional biologists. First, the very idea of evolution as '*descent with modification from ancestral forms*' predates Darwin (see below). Second, during his own lifetime Darwin's account was overshadowed in the imagination of the Victorian public by Robert Chambers' 1844 speculative work *Vestiges of the Natural History of Creation*. This book invokes quite different processes driving evolution – sometimes called a mixture of magick plus the '*inheritance of acquired characteristics*' (and following Jean-Baptiste Lamarck in this latter idea). However, it was Darwin's version that the scientists of the day preferred. His greatest achievement became recognised as his hypothesis of '*natural selection*' being the most rational explanation of the process driving evolution. This makes the notion of evolution *per se* logically acceptable as accounting for the history of life on our planet.

So, it is almost unthinkable that during the succeeding century Darwin's ideas would face serious challenges and even outright rejection from biologists. Even more so that this happened twice! Indeed, today it is well and widely understood that evolution will still proceed even in the absence of natural selection.

Biologists and philosophers now recognise that a key vulnerability in Darwin's writing was his very sketchy knowledge of genetics. Specifically, it is our later knowledge of mutational processes and the distribution of naturally occurring genetic variants that led to conflict with Darwinian thinking. This article is concerned with the second of these periods of controversy arising from Motoo Kimura's so-called *Neutral Theory*. The author of this present article devoted a large part of his early career to participation in laboratory investigations around this question and these experiences form the basis for this account. But, before one can begin to explore this topic, it is necessary to examine its origins.

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Historical background

The first few decades of the twentieth century did not start well for Charles Darwin's ideas about the underlying mechanism of evolution. In contrast, the idea of biological evolution itself survived intact and perfectly acceptable. It remained pretty much as first formulated during the Enlightenment Period (Box 1).

Box 1 The truth of evolution

French enlightenment-period scientists, notably Buffon, Cuvier and Geoffroy, prepared the way for the acceptance of the whole idea of evolution based on new information about the fossil record and new studies on anatomical relationships between living organisms. The emergent argument goes along these lines:

1. The earth and rocks are filled with the remains of strange plants and animals, some enormous in size.
2. These organisms were alive in the past but are now genuinely extinct (*v.* simply hiding behind a bush in the local park waiting for someone to stumble over them.
3. Those creatures presently living are clearly different from those living in the past but do resemble them in many ways.
4. Remains of these modern organisms are not (for the main part) found among fossil strata.
5. There must be some process by which these old and now extinct creatures were replaced, or there would be nothing walking on the face of the Earth today.
6. Therefore, it is contingent upon these facts for scholars to think that these new creatures have replaced the old ones and are derived from them by some means or other.

And amazingly enough, there it stops. Nobody came up with an explanation for how one set of beings evolved into another. Attempts were made, including by Louis Agassiz, who postulated up to 50 episodes of '*special*'* creation at the hand of the Almighty. Charles Darwin is the person who first described the causal process of Natural Selection to explain biological succession.

*Special in the sense of not included in The Bible.

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Remarkably, Darwin's central concept of natural selection was rejected by both of the two major British schools of biological thought. The Naturalists (holistic thinkers) and Experimentalists (reductionist thinkers) had both fairly readily adopted Mendel's ideas about genetic laws following their earlier rediscovery. The biologists' problems stemmed from new knowledge about '*mutations*'. Typically, these involved single genes, were of big effect and nearly always caused bad things to happen to living organisms. This meant that mutations imposed a sort of '*genetic load*' on populations in terms of losses through mortality. Hence, it seemed unlikely that a mutational mechanism would create the sorts of advantageous changes that natural selection was thought to favour. Darwinian thinking fell out of fashion and was relegated along with Lamarckian thinking (aka '*inheritance of acquired characteristics*') as most unlikely candidates as causal mechanisms responsible for directing evolutionary change (see Mayr, 1982, p. 547–548 for some fairly alarming quotations from this period).

Darwin was saved only by a scientific revolution known as '*The Modern Synthesis*'. This was an exercise in theoretical population genetics which came up with single-gene models to explain how mutational variants could remain in populations even when they were deleterious (aka '*balancing selection*'). Their models were couched in terms of '*selection coefficients*' (more about these later). This new '*Neo-Darwinian*' programme began well because biologists like Theodosius Dobzhansky and others were able to measure selection coefficients associated with chromosomal inversions in *Drosophila* and successfully test the theoretical predictions by running competitions between selected lines of fruit flies in devices called '*population cages*'. So, everything seemed to be going along fine until molecular methods made it possible for biologists to begin to measure levels of genetic variation in natural populations. The first step was known as the era of '*allozyme*[1] *electrophoresis*' where the so-called '*gel jockeys*' measured the rates of migration of enzymes and other proteins in an electric field. This was a technical proxy measure to estimate variation in DNA sequences. They argued that the sequence of bases in DNA determines the amino acid sequence of their gene products such as metabolic enzymes. The chemical structure of these protein catalysts determines their shape and surface charge, which in turn dictates how fast they will move in electrophoretic gels. At the end of each experiment their position in the gel (aka their '*mobility*') can be revealed by special histochemical staining techniques by taking advantage of their catalytic properties. From 1966 the earliest pioneers (notably Lewontin, Hubby, and Harris) upset the applecart forever by finding unexpectedly high frequencies of allozyme mobility variants (*see* Lewontin, 1974). This implied a much higher genetic load than had ever been anticipated. The situation was all made much worse by the prompt realisation that the basic electrophoretic method probably delivered an underestimate due to '*hidden*' variation; i.e. an unknown number of amino acid substitutions that did not affect mobility. Not to mention the fact that these protein-based analyses very much underestimate the underlying level of nucleotide variation in DNA, as later established. The wheel had turned full circle and created the second serious threat to Darwinian orthodoxy. Ironically it turns out that genetic load was a problem both in its own right initially, and later became one via its dismissal as insignificant!

[1]A variant form of an enzyme that differs structurally and has a different electrophoretic mobility from other forms but may or may not differ functionally from them with respect to biochemical properties.

Thus, salvation of a sort seemed to arrive in the form of Kimura's '*Neutral Theory of Evolution*'. This concept escaped the concerns about genetic load by pushing natural selection to the sidelines. In short, Kimura argued, as a primary hypothesis, that these protein variants were associated with selection coefficients[2] that were zero or close to it. Hence, they were not subject to balancing or directional selection (see later for more on these terms). In the following sections this article briefly explains the mechanics of this theory and its contentious reception by population geneticists of the time. It concludes by asking, now that the dust has settled, if this theory really did deal a mortal blow to Darwinism.

What is Neutral Theory?

In my view, the real genius of the Kimura hypothesis comes with the recognition that evolution is still possible under neutrality because (allozyme) allele frequencies will change from generation to generation simply as a result of random sampling through differential reproduction. Because natural populations are finite in size and not all individuals have the same numbers of offspring, then the genetic make-up of the population will change from generation to generation by what is described as a '*Poisson sampling process*'. New alleles will arise from time to time by mutation and their frequencies will wax and wane over subsequent generations. Some of them will inevitably increase in frequency to approach 100% (aka '*fixation*'). When this occurs the gene (and protein) sequence will have changed forever and evolution will have taken place. The species will now be permanently differentiated from all others. From there Kimura and his colleagues developed a body of mathematical theory with increasing sophistication (Box 2) to calculate rates of evolution under various assumptions.

Box 2 Types of Neutral Theory

The following list gives a brief chronological summary of the development of Neutral Theory models.

1. The Infinite Alleles Model: assumes that each new mutation is genuinely novel. This proposal was made to help to make the mathematics tractable.
2. The *k*-Allele Model: new mutations create one of a limited set (*k*) of possible varieties, an idea developed in response to criticisms of the infinite alleles model by making it more biologically realistic.
3. The Step-Charge Model: here new mutations change the mobility state of an '*electromorph*' by +1 or -1 step. This approach was taken to model typical allozyme electrophoresis data which often produced uniform '*electromorph ladders*'.
4. The Slightly Deleterious Alleles Model: a mathematical demonstration that even mutations conferring a slight fitness disadvantage on their host organisms could be maintained in populations for considerable periods and even reach fixation.

These models start from the recognition that neutral evolution is a '*stochastic*' process; i.e. goes along in a step-by-step

[2]These parameters describe relative ability of particular variants to survive a selection process. Their mathematical properties are described later in the article.

fashion and conditions at the start of one generation lead to the outcome in the next in a non-deterministic manner. So, by assuming that each mutation was the result of an entirely novel, never to be repeated, event and using what is known as the '*diffusion theory approximation*' algebra, Kimura was able to model iterative sampling over many generations and obtain end-state predictions about outcomes. The fascinating result was that his equations produced a startlingly simple formula for the rate of evolution, i.e. the rate at which one allele is entirely replaced by an alternative form. This rate = $4Ne\mu$ where Ne is the '*effective population size*' and μ is the '*mutation rate to neutral alleles*'[3]. Already by this time it had been well established that each protein evolves at its own characteristic rate and that these rates (or their reciprocal *Unit Evolutionary Period,* UEP) may differ by a factor of 20 or more, say cytochrome c (slow) *v.* fibrinopeptides (fast) – see Wilson *et al.* (1977) – and remain constant over very long periods (aka '*the molecular evolutionary clock*' after Zuckerkandl & Pauling 1962). It was clear that such UEP differences must represent differences in mutation rate and selective constraints inherent in protein molecules themselves; i.e. there are many essential amino acid residues in cytochrome c and few in fibrinopeptides. This seemed to match what was then known about the biological functions of these protein molecules. The parameter, *Ne*, was more difficult to come to grips with. Clearly, it would be less than *N* (the census population size) because not all reproduce successfully or to the same extent. The size of *Ne* would also depend on the ratio of males and females in the population. In some special cases this effect could be calculated or approximated. However, a core difficulty could not be overcome; both *Ne* and μ are quantities of uncertain magnitude and hence the compound property $4Ne\mu$ or '*neutral rate of evolution*' was even more uncertain. This is not to say that Kimura's theory did not make testable predictions. It did, but as we shall see later, they proved surprisingly hard to test.

One might think that such an elegant body of work would have been well received. On the contrary, it caused intellectual outrage among a wide group of Neo-Darwinian biologists because it denied that directional selection promoting advantageous variants was what drove evolution. Previously, this was a generally unvoiced, but apparently deeply-held conviction. So, the written response was sharp and biological scholars once again became divided, this time into the '*Selectionist*' *v.* '*Neutralist*' schools. We will next see how this all played out.

How population genetics sees natural selection

This picture is derived from the single gene-eyed view taken by the theoretical infrastructure of the Modern Synthesis. It visualises competition between variant alleles in terms of '*fitness*' and '*selection coefficients*'. The idea of fitness (Box 3) is seen in strictly evolutionary terms and reflects differential reproduction.

Thus, the selection coefficients are the relative fitness differentials between alternate genotypes viz:

Genotype	AA	AB	BB
Fitness	$1–s$	1	$1–t$

In the above formulations (after Chambers 1988) if both *s* and *t* have positive values, then the two homozygotes AA and BB will be less fit than the AB heterozygote and both alleles will be maintained in the population by balancing natural selection at frequencies dependant on the ratio (*s/t*) of these values. In contrast, if *s* is positive and *t* is negative (or vice versa), then directional selection will favour allele B (or A) and it will move towards fixation; as shown later in Figure 1. As we have already seen, this all worked perfectly well for Dobzhansky's chromosomal inversions, but what about allozyme variants?

Box 3 The various meanings of fitness

The English word 'fitness' has several meanings which might seem pertinent to evolution as was captured later in the popular '*survival of the fittest*' conceptualisation and which followed long after the publication of *On the Origin of Species.*

1. Physical Fitness: gazelles that run fastest don't get eaten.
2. Match to the Environment: in the sense of 'fitting in well' or well-suited to a particular ecological niche.
3. Most Deserving: a sort of spiritual view that those who are rated most virtuous will survive.
4. Most Fecund: those leaving the highest number of descendent offspring are said to have the highest Darwinian fitness.

It is only Definition 4 that directly applies to evolution (although admittedly advantages under both Definitions 1 and 2 may be seen to contribute). Those with highest fitness in this sense are the ones who leave the largest number of offspring who themselves contribute to the next generation.

Thus, Captain James T Cook may be said to have had high single generation fitness because he had several children in his lifetime, but rates zero overall because none of them had any surviving children of their own.

Measuring selection in molecular terms

Surprisingly there turned out to be several approaches available to resolve the Selectionist v. Neutralist controversy[4]. The first is to match experimental data to neutral models. Biochemist Walter Fitch began by asking if rates of protein evolution were as expected under neutrality. Early tests rejected the neutrality hypothesis, but these depended on having data available from multiple sequences for a single protein from a variety of species (available only rarely in those days) and these early findings must be rated as indicative at best. Another data matching exercise is to see if heterozygosity within and between populations is as predicted. In summary, a simple direct concept was ultimately compromised by a lack of sufficiently discriminating statistical tests. An elaboration of this idea is to match the numbers and frequencies of all alleles in a population to neutral theory models. Here at last there was an available statistical method, '*The Ewens-Watterson Test*' with sufficient power to discriminate. Sadly, it was by then also recognised that the data properly had to include, or allow for, all the electrophoretically cryptic variation. Only a few such data sets were ever obtained and these only via heroic laboratory exercises running gels under

[3]This is the rate at which selectively equivalent (neutral) alleles arise in the population.

[4]Selectionists held that most if not all allelic variants were associated with non-zero selection coefficients. In contrast, the Neutralist School held that majority of allelic variants had very small (effectively zero) selection coefficients. They did not dispute that a small fraction of alleles in natural populations might be maintained by balancing selection or even positively advantageous.

many different conditions (e.g., see Keith *et al*., 1985). This work rejected neutrality, but the general case is hardly overwhelming with so few examples.

The second approach was to seek causal explanations for the maintenance of enzyme variants via biochemical models. A small number of quite elegant studies were carried out to explain geographical patterns of allozyme variation in terms of kinetic constants etc. and balancing selection mediated via environmental factors. These cases are themselves limited and have a further problem. When one begins to test for biochemical differences between enzyme variants one often finds that they differ with respect to everything that gets measured. Hence it is always going to be difficult, if not impossible, to tell which differences in properties are significant and which are merely correlated properties resulting from structural differences (see Gould & Lewontin, 1979 for more on this theme).

The third approach is empirical. Neutral processes differ from those shaped by natural selection in that they are not directed. Hence, they are not often expected to result in apparently ordered patterns that persist over long periods of time or over vast geographic regions. They are never expected to produce congruent patterns repeated over time or space. Several studies including some of those described immediately above showed large-scale clinal geographic patterns of variation and others reported parallel clines[5] in different places. Overall, a slight majority of the systems examined turned out to show exactly such patterns, including correlation with environmental variables (e.g., Oakeshott *et al.* 1982). Subsequent work has shown that there may be other explanations underlying some of these observations. For instance, the apparent clines within a single species might alternately be a large hybrid zone between two closely related species or subspecies.

Finally, one has the option of following Dobzhansky's excellent example and measure *s* and *t* directly in population cages, with or without including variable environmental factors such as food type, or temperature etc. Despite an energetic following amounting almost to a cottage industry, this research programme proved to yield equivocal results. Values returned were small and highly variable, researchers gained conflicting views of the mode of natural selection even in single allozyme systems. This dilemma is captured in the visual model presented in Figure 1 and shows how difficult it is likely to be to gain an unambiguous outcome in such situations.

As a brief extension to this story the author is keen to point out that this present account is mostly concerned with protein level variation, reflecting the leading analytical technology at the time of the debate. It is now known that these protein coding genetic differences turn out to be just the tip of the iceberg. Even the very first DNA sequencing surveys showed that nucleotide substitutions were much more abundant than amino acid substitutions. This arises in part from the degeneracy of the genetic code where as many as six different triplet codons may encode a single type of amino acid. At first sight it might look as if natural selection would be blind to synonymous nucleotide changes, i.e. those that simply change one codon to another coding for the same amino acid. However, this is not necessarily a given because the t-RNA species corresponding to one codon may

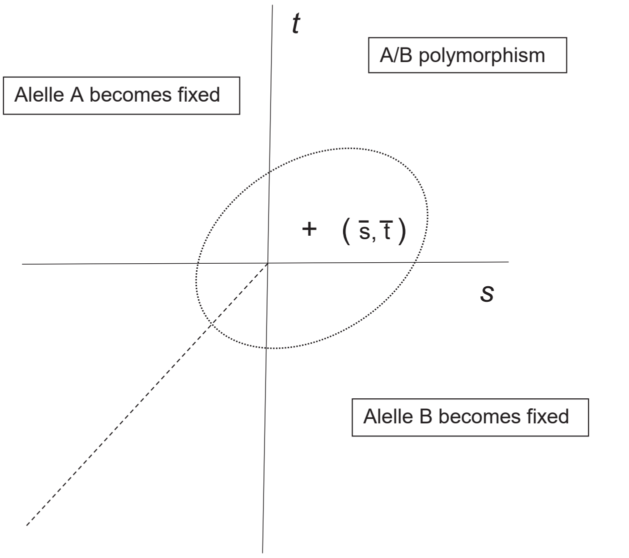

Figure 1. Representation of a simple two-allele (A, B) genetic polymorphism (see text) showing balancing selection (aka overdominance or heterosis). The axes are selection coefficients s and t for the two homozygotes AA and BB respectively. The point + marks the global mean value of s and t with a 95% confidence interval shown by the dotted ring marked around them. The dotted line in the lower left quadrant marks the boundary of an unstable equilibrium (negative heterosis) anywhere away from this line one or other allele eventually goes to fixation as shown

be more abundant in cells than its partner(s) corresponding to the alternate type(s). It is recognised that this can lead to overall differences in protein expression in turn producing differences in catalytic capacity. Further there is also a type of hidden variation problem with nucleotides due to unseen multiple substitutions at a single site that ultimately restore the original sequence. However, having laid down all these disclaimers one notes that there are now more than adequate tools for generating DNA sequences and statistical tests of power capable of testing for neutrality within and between populations and species. This is a story for another day and does not end with the advent of this methodology alone. Geneticists have discovered that due to limitations of recombination on chromosomes genes cannot be considered in isolation, but rather exist as part of an extended '*haplogroup*'. Such set ups turn out to be prone to '*selective sweeps*'. Here, even a single newly arisen nucleotide variant at one position in a haplotype may suddenly become of marked selective advantage and rapidly increase in frequency. In the process it drags along all of the other variants in its immediate haplotypic region, regardless of whether they are advantageous, neutral or disadvantageous. The single gene-view of the world becomes a marked disadvantage under such circumstances.

Is Darwinism dead?

As stated earlier in the opening section of this paper, the Darwinian view of evolution has two main components. These are known as the fact of evolution (Box 1) and the hypothesis of Natural Selection as the force which drives it via differential fitness (Box 3) among organisms. The arguments in Box 1 all but carry the day for evolution as a process of descent via (genetic) modification. However, many people will not be convinced by such arguments unless they know exactly how the process works. This is exactly why Darwin's ideas about natural selection were

[5]A cline is measurable gradient in a single character (or biological trait) in a species across its geographical range.

> ***Box 4 The logic of Darwinian Evolution***
> The following scheme is summarised from Mayr (1982) p.479–481:
>
> Fact 1: Most species have high fertility.
>
> Fact 2: Nonetheless, population sizes remain generally stable.
>
> Fact 3: Resources are limited and their supply remains generally stable
>
> ***Inference 1***: Because more individuals are produced than their environment can sustain, there must be a struggle for survival and reproductive space.
>
> Fact 4: No two individuals are the same.
>
> Fact 5: Much of the difference between individuals is heritable.
>
> ***Inference 2***: The outcome of the struggle for survival has a genetic basis (natural selection).
>
> ***Conclusion***: Over generations natural selection will induce gradual genetic change including the emergence of new species (evolution).

so important. The entire concept has been neatly unpacked by Mayr's (1982) '*five facts and three inferences scheme*' (Box 4).

Under Kimura's model the neutral theory process of '*genetic drift*' only replaces the struggle for resources and natural selection in guiding differential reproduction. The overall evolutionary scheme remains intact.

Closing summary

So an era of white hot debate might seem very much to have ended with a whimper rather than a bang. Some now might even say that the debate was not worth having in the first place – but the truth may lie far from it in the view of this author. In my opinion we are left with rampant genetic variation at the molecular (DNA) level, disappointingly small s and t values (say compared with those for chromosomal inversions) and processes additional to natural selection (including neutrality) as candidate forces directing evolution. True, there may have been no clear winner in the Selectionist *v*. Neutralist debate, but we have substantially enriched our view of mechanisms controlling biological history and the future.

Perhaps this was the right outcome because maybe there never was any real contest between neutrality and selection, except perhaps for some people's views regarding their relative significance in managing molecular genetic variation in populations. In fact, the two ideas can (and now do) rub along together perfectly well. The neutral process of genetic drift is an undeniable (and mostly undenied) fact of life for finite populations. The question now becomes: Is natural selection acting on such variants strong enough to overcome genetic drift or not? The answer very much depends on population size and structure, which are reflected in the magnitudes of N and Ne respectively.

In the last analysis we should ask: Is this what evolution (even at the molecular level) is really all about anyway? Have we, in fact, been seduced by the effectiveness of Mendelian ideas about inheritance and the fabulous success of the Modern Synthesis. The received wisdom view at the time of the Selectionist *v*. Neutralist debate may just have been too microscopic. There is indeed a bigger picture to consider. The legitimate focus of natural selection is on quantitative traits, running speed, endurance, etc. Wide experience of modern *Genome-wide Association Studies* (aka GWAS) has demonstrated that such traits are governed by very many genes, each individually of only small effect. Even genes with relatively large effects and which may have huge p values (i.e. *statistical probability*) for association may yet only account for 2% of the total variance in the trait. So, this is where a deeper truth may lie. Each of these gene variants will only be expected to be associated with small selection coefficients. In conclusion, and for the present, neutrality serves us best as an excellent null hypothesis. It does not exclude the possibility of natural selection very much in the way that Darwin first envisioned it.

Acknowledgement

Geoff Chambers is grateful to Victoria University of Wellington for support in his role as an Alumnus Scholar. He also wishes to acknowledge the valuable constructive advice he received from his colleague Dr Jean-Baptiste Grodwhol and from an anonymous reviewer for *New Zealand Science Review*.

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New Zealand banknote promotes rugby!

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It is no wonder that New Zealand has won three Rugby World Cups. New Zealand is the only country in the competition which has a banknote featuring a world famous rugby player.

Media regularly accuse New Zealand of being obsessed with rugby football. And not just because every one of its 1992 banknotes has the spirographic pattern around the map of New Zealand centred on Nelson, the reputed birthplace of New Zealand rugby.

On the morning news of 6 June 1991, the Reserve Bank of New Zealand announced that new banknotes were needed. Their existing ones were designed a quarter of a century earlier and many of their security features were about to be overtaken by colour copiers. At the same time the Bank floated the idea that the portrait of the Queen be replaced on some of the new banknotes by those of prominent New Zealanders.

A tremendous noise ensued as the Royalists collectively herniated.

Before ducking for cover, the Bank sought suggestions for names of suitable people.

Of the then population of about 3,500,000, some 400 people responded to the Bank with a mixed bag of names, such as the then wife of ageing rock star Rod Stewart, the sheep dog in a popular cartoon Footrot Flats, and the captain of the only All Black team to win the Rugby World Cup until then.

I too had a suggestion which was accepted.[1] Ernest Rutherford, internationally the most famous of all New Zealanders, was placed on the least used, but highest value, banknote, the $100 note. Therein is hidden a rugby story – of a young man grafting away in the forwards, who learned to play at Nelson College and Canterbury College and twice played on Christchurch's hallowed turf at the late Lancaster Park.

That New Zealand is a small and young country is shown by the linkages of the banknotes. There had to be a Māori. Apirana Ngata ($50 note) was a fellow student. The first Maori to enrol at Canterbury College, the first Māori graduate of the University of New Zealand, a leader of his people, and a Cabinet Minister in Parliament. He played a couple of times for a lower rugby team. There had to be a woman. Kate Sheppard ($10 note) had Rutherford's landlady and future mother-in-law, Mary Newton, as one of her right-hand women in the fight which, in 1893, saw New Zealand became the first country to allow women the vote. Mary was likely the first to sign the nationwide petition that allowed this historic moment. And Ernest Rutherford, as President of the Royal Society, was well-known to the Society's patron, the Queen's ($20 note) grandfather, who had raised him to Ernest Lord Rutherford of Nelson.

A prime requirement was that the person had to be dead, in order that they wouldn't sully their good reputation. The suite of notes is rounded out by Ed Hillary, the then only living person on our banknotes ($5). New Zealand desperately wanted him. Apparently, when asked, he turned to his wife and said 'I suppose there's not much chance of getting into trouble at my age?'

Nelson, the geocentre of New Zealand and therefore the centre of the security spirographic pattern, is where Rutherford was born and learned to play rugby.

In 1889, his final year at Nelson College, the school roll consisted of only 29 boys older than 15. As the head-boy, Ernest Rutherford, being tall and lanky, did his duty as a forward. The main worry of the master in charge of rugby, 'Porky' Littlejohn, centred on how to field a passable team. Of the previous year's team, only two forwards and two backs had returned. The new squad were all raw beginners. Littlejohn was Rutherford's maths and science master. His nickname came from the lazy schoolboy's version of the French translation of Littlejohn's persistent query encouraging his pupils to think, why? why? why? (pourquoi).

All games were played in the Botanic Gardens or the Park. The first match of the season brought a loss to the inexperienced College team. Few of the forwards could control their feet (which wasn't surprising as they played in smooth-soled street-boots), and still fewer kept on the ball. Rutherford gained a mention as one of the five College forwards who played well enough, according to the rugby reporter who wrote under the pseudonym 'Pass' (actually Mr Littlejohn.)

The team played once a fortnight against the three other teams of their standard. The second match saw an improvement and a further loss. 'What with a better knowledge of the rules, a decrease of adipose tissue, and an increase of experience and

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John Campbell is the author of "Rutherford Scientist Supreme", "Rutherford's Ancestors", www.rutherford.org.nz, and was the producer of the three-hour documentary "Rutherford". This article is based on events scattered throughout several chapters of his book. He pushed for Rutherford to be one of the New Zealanders on the new bank notes and helped design it, supplying the image of Rutherford, the Nobel Medal, and the curves of the growth and decay of radioactivity. The banknote was issued in November 1992 and modified with updated security features (but dropping the Spirograph pattern) in April 2016.

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skill, the combatants fought a good fight ...' Rutherford was to be cited in six of the eight games that season ... 'Rutherford by his fine following up and good tackling, being the best' (of the college forwards) ...' 'Rutherford especially doing some good dribbling.'

Unfortunately in 1889 the team achieved a poor record of one win, one draw, and six losses. Nonetheless, under Mr Littlejohn's dictum of persistence, most, if not all, would have played their hearts out, for 'Porky' taught by example. They would have recalled his performance on the cricket field at the time when the then, new, headmaster and well-known batsman Mr Ford, was visited by a friend from England who was obviously another first-class cricketer. A friendly match with these two opening degenerated into a competition to see who could score the most runs. When the boy bowlers were spent, it was Porky Littlejohn who left his wicket keeping to take up the battle. For over an hour he tried every kind of bowling but to no avail. Ernest Rutherford, a spectator at the game, recalled in later life for Porky's biography[2] '... I never saw a better example of grit and persistence in an unequal contest. He refused to give in, and attacked with the light of battle in his eye ...' 'The whole episode left on my mind an enduring impression of courage and resource under difficulties, and, though technically defeated, I thought he was the true hero of the occasion, notwithstanding the brilliant display of pyrotechnics by the batsman.'

Further evidence of the team's poor year is that Nelson College proudly displays photographs of all its early rugby teams, but no photograph appears to exist for the 1889 team.

Nelson College had a great influence on Ernest Rutherford's development. Later in life he still recalled many of his experiences, both pleasant and unpleasant. He had vivid memories of his life in the dormitories, for on occasions he literally had to fight his way through them. Joining the school at the late age of fifteen probably shielded him from many of the unsavoury episodes usually inflicted on young new chums. With the passage of time the memories of the unpleasant events fade while those of pleasant occasions grow. As he lay on his death bed he turned to his widow-to-be and emphasised 'I want to leave a hundred pounds to Nelson College. You can see to it. Remember, a hundred to Nelson College!'

Rutherford, after one failure, finally obtained a University of New Zealand scholarship which took him to Canterbury College in Christchurch for 1890. The College rugby club fielded three teams. After a few weeks, the list for the third team included for the first time 'Rutherford'. Of the sixteen names listed, he and another were bracketed as the reserve. The team trotted onto the Cranmer Square ground to play Merivale Thirds. A noteworthy game ensued. College scored a converted try in the first spell. A quarter of an hour later the referee disallowed the try when he discovered that College had sixteen men on the field.[3]

This seems to have been Rutherford's only appearance of the 1890 season.

In 1891 he had a permanent place in the third of the three college teams. It was an undistinguished year, with his team being thrashed most weeks, even by the Lyttelton juniors second fifteen.

That year a ladies' football team toured New Zealand. This event caused a lady society gossip columnist to remark that 'No ladies should play and I fancy the "appreciative crowd" would not be composed of the gentle sex.' [4] (The tight restraints on women were further loosened that year following a report in a British medical journal. Several female monkeys had died of suffocation after being encased in plaster of Paris jackets to imitate corsets.[5])

During the 1892 football season Rutherford was again undistinguished at rugby. He oscillated between the second team, the third team, and oblivion. (Perhaps the latter signals this as the year he injured his knee which was to plague him in later life.) With the second team he participated in one forfeiture (the college had trouble raising even one team during university vacations; Rutherford, for one, regularly returned to his home in Taranaki), two postponements (due to rain), three losses, and one win. His real success that year was to pass his BA final exams.

In 1893 Rutherford returned to Canterbury College for a master's degree in mathematics and physics. So began his illustrious research career. (For someone who in 1890 didn't appear to be able to add up to 16, it is curious that it was a mathematics scholarship that financed his 1893 year.) Perhaps rugby losses helped him to quickly pick himself up whenever an experiment didn't proceed as expected. The rugby club elected him assistant secretary. College could field only two teams, with 21-year-old Rutherford immediately going into the first team.

He played in the first competition game of the season at Lancaster Park before a paying audience (admission sixpence, ladies free). That Saturday dawned with the grounds wet and slippery, but the rain held off. College started the season well, and in a very even game, much appreciated by the spectators, they defeated Christchurch 10–7.

From there on it was mostly downhill. With one game cancelled because of a snow storm, and two forfeited through not being able to raise a team, College finished the season as bottom team. They won two games, drew one, and lost the rest, even though most losses were in games described as fairly even contests. The club was not healthy, and by the end of the season they struggled to raise even one team.

Rutherford did receive sporadic mention in the newspapers. Occasionally he assisted or was prominent in the forward rush – 'A College rush, led by Morris, Rutherford, Haast and Dawson was stopped at the East 25 ...' and once ' the College line was again in danger. Rutherford, however, dribbled to the centre'.

That year was Canterbury College's turn to visit Otago University. When the maroons and the blues met on the field of battle the day was right – fine, with a light breeze that carried dense volumes of smoke across the ground from the local brickworks. The conditions were right – the ground in good order and a fair number of spectators were present. The players, however, were not right. Otago University, like Canterbury College, graced the bottom of its league. Even though Otago boosted its team with two ex-provincial players the game was tediously slow and uninteresting. '**...** some life was infused into the game by a capital passing rush, in which Buchanan, Rutherford, Gibson and Dawson participated, which shifted the play into the Varsity quarters where Cresswell obtained possession and nearly dropped a goal.[6] Canterbury led 4–2 with five minutes to go, but Otago scored two late tries.

Ernest Rutherford couldn't get a job in New Zealand. On three occasions he failed to get a schoolteaching job. It was enough to drive a young man overseas. Every second year one scholarship was offered to New Zealand for a graduate to go anywhere overseas to conduct research of importance to the nation's industries. So in 1894 Rutherford returned to Canterbury College with this scholarship in mind. He continued his researches, which were at the forefront of electrical technology.

To be a candidate for the scholarship he had to be a registered student so he enrolled for a BSc degree in geology and chemistry, his third degree.

The football club elected Rutherford as a committee member, and as a selector. Two teams were entered in the Saturday competitions and one in the Thursday competition against commercial teams (e.g. Drapers, Hardware). Little success fell to the College teams – they were invariably beaten if not thrashed. Complaints were made that elements of professionalism were creeping into the game in Christchurch. It was hard times and good players were given jobs. But this did not explain College's poor performance. Regrettably, football at Canterbury College was in decline. During the mid-year vacation it could not even scrape together one team.

The first team finished bottom of the senior competition. Their standard was so low that when they played Otago University at Lancaster Park most of the 1500 spectators watched an adjacent game. Appropriately, the university match resulted in a scoreless draw. The game against Linwood was described as not worthy of a senior contest and many spectators wandered off to watch a junior match.

Once again Rutherford played a relatively undistinguished role in the first team. Occasionally, he rated a mention in the newspaper reports. 'Afterwards the maroons, headed by Hawkins, Gray, Rutherford and others, made a determined charge' ... 'Dawson, Gray and Rutherford worked well in the scrum ... Hawkins and Rutherford best in open'.

In one highlight of the season, Rutherford scored a try against Drapers during one of the team's few wins.

The true measure of Ernest Rutherford may be found in the last game of rugby he played. College were at the bottom of the table; the day was wet and cold. By half-time Christchurch was beating College 8–0. Then the College forwards came to life. Rutherford took the ball to the Christchurch twenty-five and Craddock completed the move by potting a goal. 4–8. Rutherford picked up at the centre and ran again to the opposition's twenty-five. As he went down in a tackle he threw the ball behind him, where Dawson took it on the full and scored. 7–8. Alas, there was no fairy-tale ending. The try was not converted.

The poor performance of the College football teams during 1894 was not entirely the fault of the team members but part of the general malaise beginning to pervade the undergraduates. A capping day song captured the mood (Tune – All Doing a Little Bit).

Oh sacred nine assist me as I sing my modest lay
About a certain College, which is famous in its way,
Successes academical have won for her a name,
Her sons however, sadly lack all love of manly game;
The undergrads have seemingly no stout esprit de corps,
As we return defeated, trailing homewards from the park,
The fops are always ready with some would be smart remark.
CHORUS
They drawl-as they-cadge from you a fill.
"Aw! have you really been put down by 20 points to nil."
But they would not soil their collars,
Oh, no; not for "fawhty" dollars.
The thought really makes them ill.

This reality flew in the face of a motion debated by the College's Dialectic Society: 'The tendency at the present time is to overestimate the value of athletics'.

The final song of the 1894 capping day concerned the football team, in praise in particular for the man who scores the try. Its final verse enthused:

Five minutes yet to time, boys – now just another point,
O tempora, O mores,
Oh Dawson, Speight, and Rutherford – just sweep them off the ground
O tempora, O mores,
I told you so – they're over!
Upon the ball they lie,
Hurrah! Hurrah! Hurrah!
O tempo – tempora
All glory to them all for all have scored the try.

Even the Science Society lost spirit that year. The secretary, gave his, and his committee's, view of the undergraduates in the draft of the annual end-of-year report. 'Like other of our college institutions this society has not received the support of the present race of undergraduates who it must be confessed are of a degenerate type. They have either dropped all enthusiasm, or else they reserve it for their text books. If this meeting therefore should be of the opinion that this undesirable state of affairs is likely to be of long duration, it is evident that it would be necessary to consider the question of suspension or of reconstruction. If the society is to continue and flourish it must receive the support of some few at least of undergraduate scientific enthusiasts. The rest they leave to you'. 'You' did not pull his weight. At the end of 1894 the Science Society went out of existence.

It is ironic that Ernest Rutherford was to obtain his research scholarship solely because the only other candidate was awarded the scholarship nomination but then withdrew. He held a job which paid more. So by chance Rutherford went overseas, and chose to go to Cambridge University. The rest is history.

The people in the Cavendish Laboratory could only lament that such a large fellow did not play. His dicky knee meant his football playing days were over. But his career in science was to blossom. Not only was he to set the world record for the distance over which electric wireless waves could be detected, he later explained radioactivity (for which he received the 1908 Nobel Prize in Chemistry) as the natural transmutation of atoms, dated the age of solidification of the Earth's crust, invented the Rutherford-Geiger tube (later to become the Geiger-Muller tube), determined the nuclear structure of atoms, and become the world's first successful alchemist. Furthermore, the principles of the household smoke detector can be traced to some of his earliest experiments in Canada, when he blew tobacco smoke into his ionisation chamber.

Though he always seemed to play his heart out, Ernest Rutherford's rugby career was undistinguished. But it was an example of what we are in danger of losing in this professional era: grass roots rugby played not for financial reward but for comradery, enjoyment, and team spirit.

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Public Statement 1 December 2020

Renewing the Aotearoa New Zealand Science System: Summary

The New Zealand Association of Scientists

The effects of Covid-19 reveal some of the cracks in our science system. This points to the need for its review and renewal. Covid-19 now, and climate and biodiversity very soon, will require a different way of valuing and connecting with science. The NZAS proposes an eleven-point wide-ranging and empowered review of the science system.

1. Start by valuing people - make them, their careers, and their communities, the foundation of a good science system. Build a culture of inspirational ideas and knowledge that is grounded in what is possible locally.

2. Sow and nurture the seeds for more Māori and Pasifika scientists and their pathways to contribute and benefit.

3. (Re)Create a Ministry focused on Science and Research in a way that balances ministerial connectivity with all the aspects of Aotearoa New Zealand that stand to benefit from science and research.

4. Develop better pathways for science and policy to connect – and communicate how this works to all stakeholders.

5. Improve alignment across the system so that components work together rather than in competition.

6. Clarify and support what universities and government-funded research institutes are for and support that at the board level.

7. Science for the nation – would a new version of DSIR (Department of Scientific and Industrial Research) do better than separate institutes?

8. Develop a better approach to key challenges faced by the nation, by improving the ways in which teams and organisations are brought together to tackle them.

9. Build a nuanced understanding of our place in global research and what is preventing better collaborations.

10. Determine pathways to leverage from Aotearoa New Zealand's non-science strengths.

11. Develop processes to generate the data and evidence to assess the system and its impact.

A connected, evidence-based, adequately funded, harmonised research ecosystem is a goal we need to pursue. Now is the time.

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Renewing the Aotearoa New Zealand Science System: The Long Read

The New Zealand Association of Scientists

What are we talking about?

This is a call for a wide-ranging review - with teeth. Socioeconomic pressures from Covid-19 and the climate emergency suggest globally and nationally we are at a crossroad. We outline the motivations for rethinking and reorganising the Aotearoa New Zealand science system - its purpose and structure - to give us the information and tools to take the best path possible for the challenges ahead. This is not a complete plan. It is a call for a wide consultation and more data with which to make decisions.

Why do we need to do this?

A number of things going on at the moment are throwing a spotlight on science and society in different ways. The range of national responses to the present pandemic is doing a very effective job of demonstrating the benefits of connecting science with positive outcomes for society. This is against a background of a changing climate and social inequality struggling to have any impact on decision-making over recent decades.

The science and wider research sectors have undergone significant corporatisation (by which we mean a primary focus on financial outcomes) over recent decades. While this has enabled apparent expansion, it has also exposed weaknesses and raised questions about the sector being fit for purpose.

Due to their expanded reliance on international students, universities are entering a period of massive financial stress. The Crown Research Institutes (CRIs) have just been reviewed and found to be overly business-oriented at the cost of some of the driving motivations for their existence[16]. At the same time, they are being protected from many of the risks of actual commercial operation because some components are vital for national interests. Other agencies like museums and independent research organisations fill key niches in the research ecosystem and face their own specific challenges.

Meanwhile our climate is changing in ways that will have both direct and indirect effects on our environment and economy. Our land, freshwater and marine ecosystems are being placed under close-to unbearable pressure. What if solving this was part of the answer to living better lives?

Society struggles more than ever with inequity. What if improving this in an evidence-based fashion was part of the answer to having a better society?

It is not certain by any means that our present science and research sector was fit for purpose prior to the new reality of a global pandemic, and it clearly will need to adjust to our new reality. The science system could muddle along, and we plan on chance to get us through. Currently, we rely on the belief that scientists chasing contestable (with an opaque decision-making process) and commercial funding will head in the right direction. The current crisis calls this out as lacking the vision and strategy a national science system deserves. There must be a better way driven by a combination of evidence and horizon-scanning.

What's working now?

Clearly not everything is broken, and the review would want to identify and protect those things that are working well. What are they? Some components of our science system are clearly agile. During the initial stages of Covid-19, even though the field had been under-supported there were still enough scientists with enough connections to policy and decision-makers to rapidly provide an evidence base to those decision-makers and to motivate the population to support those decisions[3]. A look at what's working in comparable socioeconomic systems is something often raised. But really are there any comparable systems? Saying that, a recent Danish review is worth reading[12].

It is one thing to say the government sees a use and benefit for science and knowledge. What do the public think? It is fair to say on balance 'science' has a social license to operate generally but how far does this go, and can it be better developed bi-directionally?

It is not all about the money. Many of the present portfolios (Marsden Fund, HRC: Health Research Council, CoREs: Centres of Research Excellence, Endeavour, Te Pūnaha Hihiko: Vision Mātauranga Capability Fund[10]) are ok although success rates and transparency need to be improved. Some are hazy (SSIF: Strategic Science Investment Fund, Unlocking Curious Minds) and others are possibly a disaster (NSC: National Science Challenges) but with no independent data who knows? Indexing of funding, actual evidence of a review process and meaningful assessment to restrain expectations are starting points.

Pretty much every review of the science system concludes that certainty and continuity is very positive, so we are by no means suggesting we rush towards complete upheaval. At the same time, it is clear the system can, and must, do much better.

What's gone wrong?

What has society lost by making the connection between economic growth and science the singular pillar of our science system? For starters it is a narrow view of 'economic growth' that doesn't directly factor in the environment and social well-being[8].

In some ways it is hard to know where to start. Science is built around evidence, but we have precious little data on our science system. Existing data with which to make decisions for re-building a better research system are fractionated and hidden as one can cobble together only limited data from PBRF (Performance Based Review Fund), budget tracking, CRI annual reports and partially available grant information. The delays on the MBIE NZRIS (New Zealand Research Information System) are holding the system back.

The method which was developed to tackle actual challenges can't really be said to have worked well. The National Science Challenges (NSC) devolved into an archipelago of topic-based research ecosystems all behaving as island ecosystems do - insular and idiosyncratic. Probably the worst tragedy of all was the amount of money spent on governance rather than ideas, application and nurturing the next generation. The proposed review needs to reflect on the mid-term roll-over of the NSCs which occurred without a single visible modification and why there was no Challenge focused on infectious diseases.

Existing policies have allowed research funding, CRIs and Universities to be governed largely by neo-liberal thinking, with only short-term steering toward the next perceived opportunities. The short-sightedness is perhaps best represented by having our main science funding run out of the government's economic development agency (MBIE). We live in a time when this mode of thinking, and the motivations it has created, are being robustly questioned globally, and so it should be, as we seek to rebuild conceptual foundations of our science system.

What should the Review do?

People: Much of the government talk around shaping the science system is top-down. In some situations, this might be fine. However, our science system's unpreparedness for Covid-19 makes it questionable that the system (as opposed to notable individuals and teams) actually worked. The process must start by valuing people - make them, and their careers, the foundation of a good science system. Then it should build a culture of inspirational ideas and knowledge grounded in what is possible locally. Mandate a healthy and diverse workforce and career-path. This specifically includes early career researchers[6] and technicians[14]. This also includes boosting investigator-led science. This is as much about the resilience and productivity of the research ecosystem as it is about the well-being of individuals.

Honoring te Tiriti: Sow and nurture the seeds for more Māori and Pasifika scientists in ways that build pathways for them to benefit from, and contribute to, science[9]. Like every aspect of life in Aotearoa New Zealand there is an ethical motivation to understand and connect with Māori perspectives on science. The opportunity is there to shift the too common perspective from one of a difficult obligation to an equitable benefit. Furthermore, there is an opportunity to mature the expectations placed on Māori scholars. With all the posturing by all parties around the Vision Mātauranga initiative[10], very recent actions at the University of Waikato[13] throw light on potentially deep-seated problems.

A Ministry? Noted economist Joseph Stiglitz attributes the truth source of success as being due to science, technology and the rule of law[15]. Can we (re)create a Ministry focused on Science and Research in a way that balances ministerial connectivity with all the aspects of New Zealand that stands to benefit from science and research. The present ministerial setup has science held within economic development, which can directly be at odds with other aspects of science like environment and health. It is also likely not good for economic development in the long run because it removes understanding of the wider scientific process in supporting the economy. Evidence of this can be found in the present struggles MBIE are going through actually explaining what 'Impact' is. The review would examine the MoRST/FRST/MSI model as well as international models and recommend something that builds on this. Denmark has a Ministry for Higher Education & Science, Norway Education and Research, South Korea has a Ministry of Science and ICT.

Science and Policy: Develop better pathways for the science-policy nexus and elevate their profile and the role of science in the Nation's policies. Covid-19 has thrown a spotlight on the effectiveness of evidence-based policy and open lines of communication between science, policy, decision-making and communication. Visibility of Ministerial CSAs and their profile needs to be considered[1].

A functional ecosystem: Build alignment across the system so that components work together rather than in competition - both in the public and public-private sector. A connected, evidence-based, adequately funded science ecosystem plus an improved transferal of skills across sectoral divides

The Purpose of Institutes: Clarify and support what Universities and government funded research institutes are for and support that at the board-level. The highly corporatised modern university will need to re-vision itself, and be supported to do so, in a way that strikes a different balance between revenue and the pursuit and passing-on of knowledge.

Science for the nation: Do we build a second version of DSIR? The Te Pae Kahurangi 2020 CRI Review[16] essentially recommends something not dissimilar to DSIR. DSIR was broken apart for some valid reasons. Let's return to a for-the-nation research institute that is better internally connected and with manageable internal politics and resource allocation processes? It would connect with the universities sufficiently functionally to maintain a sustainable scientific workforce.

Actual Science Challenges: Develop a better approach to key science challenges and the ways in which teams and organisations are brought together to tackle them. Make Challenges open and dynamic.

International: Build a nuanced understanding of our place in global research and what the present limits are on better collaborations. Recent advances in remote collaboration and communication can enable better, and more sustainable, international collaboration.

Determine pathways to leverage from Aotearoa New Zealand's non-science strengths: We, as a nation, are good at a number of ways of working outside of the research sector. Number-8 wire and flat hierarchies are arguably such niches, give or take a pandemic. Where can the connections to science be developed, expanded, communicated to the wider stakeholder communities and built-upon?

Evidence: Develop processes to generate the data and evidence to assess the system and its impact. A connected, excellent research ecosystem that has impact is a great target. It is meaningless if the definitions are hazy, contradictory or unobtainable. Identifying what is measurable and doing that is a start. The lack of information with which to make informed decisions in our research system is as remarkable as it is disappointing. NZRIS is taking too long - why? A new equivalent to the 2008 NZAS Survey of scientists and technologists[7] would generate data and understanding – especially around our early career researchers where information is so important[10]. The data collection would need some independence and ability to examine the truth. It would also include transparency in decision making.

This call is for a review of the sector driven by lines of evidence for a rebuild of many parts. A connected, evidence-based, adequately funded, harmonised research ecosystem is a goal we need to pursue. Now is the time.

Acknowledgement

We thank several anonymous reviewers for their comments and suggestions.

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One Health Aotearoa: a transdisciplinary initiative to improve human, animal and environmental health in New Zealand

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Abstract

There is increased recognition that complex health challenges at the human-animal-environmental interface require a transdisciplinary, 'whole-of-society' approach. This philosophy is particularly pertinent in Aotearoa-New Zealand because of the country's relatively isolated island ecosystem, economic reliance on agriculture and its intensification, and existing indigenous worldview that emphasises holism and interconnectivity between humans, animals and the environment. In New Zealand, the One Health Aotearoa (OHA) alliance was established in order to better connect researchers and to address a growing number of infectious diseases challenges. The emphasis of OHA is to bring together and facilitate interactions between people from diverse disciplines, link to stakeholders and communities, and engage with policy-makers, government operational agencies, and funders, thus providing a holistic and integrative systems-thinking approach to address priority questions and achieve desired outcomes in One Health. The initial focus of OHA has been on infectious diseases, but there is increasing recognition of the potential benefits of the alliance to address broader complex issues. Greater involvement and overlap of the environmental sciences, human and animal health sciences, social science, and indigenous kaupapa Māori research is particularly critical for ensuring its success within the New Zealand context. Given the economic and cultural importance of New Zealand's 'clean, green' image, a One Health approach that draws strongly on the environmental sciences makes particular sense. Furthermore, as the global environment becomes increasingly stressed by anthropogenic pressures our research may hold potential solutions for similar challenges elsewhere.

***Keywords**: One health, New Zealand, Ecosystem, Indigenous, Infectious diseases*

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Introduction

There is growing recognition that complex health challenges at the human-animal-environmental interface require a transdisciplinary approach [1, 2]. In New Zealand, the response has taken the form of the One Health Aotearoa[1] (OHA) alliance, established in response to a raft of increasingly complex anthropogenic pressures and growing health challenges that are difficult to address through a single discipline.

Despite several defining characteristics that make New Zealand an obvious place in which to undertake One Health research, our history has been to remain relatively siloed in our activities. This is particularly surprising given the indigenous Māori worldview and knowledge system that emphasises holism, transdisciplinarity and interconnectivity between humans, animals, and the environment.

In order to address this discrepancy, OHA was established with the explicit intention of breaking down traditional silos and bringing together leading New Zealand researchers from a wide range of disciplines and institutions, who can work collaboratively to build transdisciplinary capacity and innovation in partnership with stakeholders and policy-makers. OHA aims to be the national leader for research, education, and advocacy on health hazards at the human-animal-environmental interface, and to be the prime point of contact in New Zealand for engagement and collaboration in One Health. OHA is not simply a national One Health society, committee or interest group. The intention is to create a genuine culture change with the embedding of transdisciplinary thinking and action among researchers at a national level, running parallel with an indigenous worldview and with intrinsic and direct links to effective policy-making. We believe this initiative is novel globally because of these characteristics.

Here we describe the background, structure and aspirations of OHA.

[1] https://onehealth.org.nz/

One health: an obvious approach in the New Zealand context

The One Health approach is an obvious fit within the New Zealand context, and several characteristics suit a transdisciplinary, 'whole of society' approach. These features include New Zealand's relatively isolated ecosystem, strong economic dependency on agriculture and the physical environment, heavy reliance on freshwater, and a tight-knit scientific community well-aligned with an existing indigenous Māori worldview that emphasises holism and interconnectivity.

New Zealand's ecosystem is defined by its physical island geography, a notable lack of indigenous terrestrial mammals, and comparatively late settlement by humans [3]. Quarantine measures were implemented early during the period of European colonisation to protect public health and the agricultural sector. Today, New Zealand's biosecurity laws remain some of the strictest globally [3]. Consequently, New Zealand has relatively low rates of certain infections (e.g. bovine brucellosis has been eliminated and Q fever has never been reported), has the presence of strains rarely found elsewhere that arrived in the country many decades ago and have been evolving in isolation (e.g. *Campylobacter* [4] and Shiga toxin–producing *Escherichia coli* [5]), and experiences delayed impact of many infectious diseases from overseas [3]. One benefit of being a relatively 'closed system' for some food and agricultural products is that the impact of health interventions can be evaluated in a more rigorous way that would not otherwise be possible. For example, campylobacteriosis rates were halved following an intervention that lowered contamination of fresh poultry [6–8].

Conversely, New Zealand has a relatively high burden of certain infectious diseases. Leptospirosis remains an important occupationally-acquired infection in farmers and meatworkers [9]. New Zealand also has an unusually high incidence of yersiniosis in humans [10], and salmonellosis [11], giardiasis [12], and cryptosporidiosis [12] are relatively common. The incidence of *Staphylococcus aureus* infections in New Zealand is among the highest reported in the developed world, with the highest incidence among Māori and Pacific Peoples [13]. The incidence of serious infectious diseases has also increased markedly in New Zealand over recent decades, and ethnic and social inequalities have also risen [14]. A major challenge for the country is to address the social, cultural, and environmental determinants of these high rates of infectious diseases and inequalities.

New Zealand also has high pet ownership, providing opportunities for transmission of certain zoonoses, with 64% of households owning companion animals [15]. Additionally, rates of international travel by New Zealand residents are among the highest globally, and net gain migration remains high [16]. Consequently, New Zealand remains vulnerable to pandemics and other global emerging disease threats.

Another defining characteristic of New Zealand is our strong economic reliance on agriculture, unusual among developed nations. New Zealand is experiencing some of the highest global rates of agricultural intensification [17], with implications for water quality and disease profile. While the global biomass ration of livestock to humans is ~2:1 [18], in New Zealand it is ~25:1 [19]. Agricultural intensification has been linked to water contamination [20], which has been associated with New Zealand's high rates of zoonotic enteric disease [21]. Zoonoses associated with direct animal contact, such as *Salmonella* Brandenburg [22] and leptospirosis [23,24], disproportionately affect farmers and meatworkers, and people living in rural areas with large cattle populations are more likely to be infected with Shiga toxin-producing *E. coli* [25]. There is growing concern over the deteriorating quality of New Zealand's natural environment, particularly freshwater quality [26]. Routes of transmission to humans via contaminated water include through irrigation of food crops, recreational activities, Māori customary resources, consumption of contaminated shellfish, as well as through drinking water. New Zealand's disease profile at the human-animal-environmental interface is, therefore, likely to be different from many developed countries, characterised both by the need to deal with internal challenges and to resist external pressures from overseas. There is growing global focus on the health and environmental impacts of food production systems [27]. It is a challenge for a country that is so highly reliant on a narrow agricultural base to transition to a more sustainable and low risk agricultural system. Informing this transition may benefit from use of new, more comprehensive metrics that consider wider health, social, environmental, and economic impacts [28].

Finally, New Zealand's scientific community is small and well-connected. New Zealand's modest population of 4.9 million makes connecting with researchers, communities, and policy-makers relatively easy, while the centralised government system means fewer layers of bureaucracy to work through. Consequently, scientific research is relatively unified nationally, and standardised country-level interventions can be created, such as the New Zealand Antimicrobial Resistance Action Plan [29]. Examples of streamlined services include a national veterinary laboratory (The Animal Health Laboratory) and a centralised surveillance system for notifiable diseases (EpiSurv). The New Zealand Microbiology Network connects all clinical diagnostic microbiology laboratories across the country and facilitated nationwide initiatives with relative ease, such as a national surveillance study for Legionnaires' disease [30]. New Zealand has a strong international reputation in biosecurity and food safety, and in 2016 established the New Zealand Food Safety Science and Research Centre as a nationwide partnership between government, the food industry and research organisations [31]. More broadly, the establishment of alliances across the health sector in parts of New Zealand has resulted in some of the most highly integrated health systems in the world [32].

Importantly, concepts of holism and interconnectivity between humans, animals and the environment are also reflected in an indigenous Māori worldview. Therefore, One Health is not necessarily a new epistemological concept in New Zealand; rather, it seeks to encourage new approaches and wider discussion to science and research that draws on previous perspectives, knowledges, and understandings, to promote new opportunities for sharing research and knowledge to understand increasingly complex systems and challenges that affect health. The One Health approach can, therefore, embrace societal and indigenous perspectives and values and, within this wider context, offers an opportunity to work closely with Māori to form a mutually beneficial partnership.

One Health Aotearoa

OHA is an alliance of researchers whose central goal is to improve health and well-being in New Zealand by reducing the burden of infectious diseases and inequalities through integrated, cross-sectoral, and 'whole-of-society' approaches to health hazards at the human-animal-environmental interface. A strong emphasis of OHA has been on facilitating the interactions of people from diverse disciplines and knowledges, linked to high-level engagement with policy-makers, government operational agencies, and funders. The intention is to use a more holistic and integrative systems-thinking approach to develop carefully targeted research questions and setting research priorities within an integrated framework. This provides a better platform for innovative, relevant and explicit research activities and opportunities. Importantly, issues are addressed in a real world context, with early involvement of key stakeholders to help co-design research, development of research questions, and easier translation of research findings into policy and actions.

Several national issues were catalysts for OHA, including a relatively high incidence of enteric infections, the potential adverse health effects of dairy intensification, threats to freshwater quality, and concerns about imported infectious diseases. In 2013, OHA was established with the aim of formalising existing connections, developing new research collaborations by offering a forum to discuss and align research priorities, and providing direct links to stakeholders, communities, and policy-makers. The initial focus of OHA has been infectious disease, but there is increasing awareness of the potential benefits of such a transdisciplinary alliance to address other issues, such as the effects of climate change and changing land use on ecosystem health. This has enabled a focus on health hazards at the human-animal-environmental interface, not just on zoonoses.

Although having no institutional boundaries, OHA was founded around a core alliance between New Zealand's oldest medical school (University of Otago), New Zealand's only veterinary school (Massey University), and the New Zealand Crown Research Institute of Environmental Science and Research (ESR), which is the main provider of infectious disease services to the Ministry of Health. OHA now engages researchers and professionals from many of New Zealand's universities, crown research institutions, government agencies, and district health boards. There is also a heightened awareness that OHA should not be solely focused within New Zealand's borders, and increasing efforts have been made to work with regional partners in the Pacific and Australia.

While OHA was originally established by the medical and veterinary professions, which have typically dominated One Health initiatives, there has always been ambition to widen traditional One Health philosophy and concepts to embrace other research disciplines and knowledges. We believe this approach to achieve transdisciplinarity is better placed to address a range of complex issues and to achieve desired sustainable development outcomes. This wider scope requires a strong cohesive and resourced alliance to facilitate change where interaction, collaboration, and integration become the norm across a broader range of disciplines and knowledges. OHA strives to aggregate the learnings from One Health, EcoHealth and Planetary Health domains and reflect their intent, mission and objectives, to facilitate inclusiveness and integrative approaches. Interconnection and interdependencies between the environment, human and animal health also lie at the heart of indigenous Māori epistemology. Understanding these intimate relationships and connections will require undertaking greater social science and kaupapa Māori[2] research within One Health. A key learning from the 2013–2016 West African Ebola outbreak response was the early involvement of medical anthropologists who were instrumental in identifying key cultural and social practices that were contributing to transmission and impairing control efforts [33]. Likewise, integration of indigenous knowledge into environmental planning and decision making has been a core component of the management of water catchments in New Zealand [34, 35].

OHA further recognises the critical need to build meaningful relationships with indigenous Māori in One Health research in New Zealand and to identify their perspectives and priorities; to date, indigenous research has lacked depth and capacity. We also base this on the Treaty of Waitangi,[3] which provides a foundation and principles in New Zealand on which to establish and build partnerships with Māori. The process adopted within OHA includes creating opportunities and advancing support for collaboration with Māori and Māori undertaking their own research.

Partnership with Māori is also a response to major health disparities in New Zealand, where Māori are over-represented in many health statistics, including infectious diseases [14]. OHA believes giving recognition to indigenous knowledge and values and respecting the importance of mātauranga Māori (knowledge created by Māori according to their experiences, history, world-view, values, culture and aspirations) is vital to its success. In terms of an integrative OHA philosophy, understanding the links between environment, human and animal health are significant for Māori. For example in the water quality area, mahingakai (traditional Māori food and natural resources and the places they are sourced from) is a major customary activity impacted by agriculture and animals, which has great consequences for human health. Therefore, an OHA imperative is for greater partnership with Māori researchers and communities, to help co-design research to collectively address these types of issues. An ultimate aim is to improve health and wellbeing for Māori, and build capacity and diversity in the way we work, through using local knowledge next to science.

OHA has focused on forming a solid base around its founding institutions and raising its profile and influence throughout New Zealand, currently funded mainly from internal sources within founding institutions. It hosts a highly successful annual symposium held centrally in the nation's capital city, bringing together a diverse range of researchers, professionals, government agencies, and policy-makers. OHA has successfully brought together a large and growing group of researchers and stakeholders who now know each other. It has grown and nurtured cross-discipline engagement to facilitate and guide new directions in collaborative research, increased dialogue between environmental, human health, and veterinary sciences, and en-

[2]A philosophical doctrine, incorporating the knowledge, skills, attitudes and values of Māori society.

[3]The Treaty of Waitangi was signed in 1840 between iwi/hapū tribal Maori groups across New Zealand and the Crown and gives recognition to indigenous rights and equality. The Crown is the Queen of England and representatives being the New Zealand Government today.

gaged widely with government science advisors, professionals, international networks, and kaupapa Māori researchers. OHA is being increasingly recognised by government bodies and others as a national resource for expertise in infectious diseases and One Health, and OHA is now widely represented on key national committees and working groups. OHA has represented New Zealand on international initiatives such as the Oceania Planetary Health Forum, and aspires to be recognised as a centre of research excellence.

Priority research areas

OHA has identified several research priorities, three of which have been developed into focussed work streams, or pou (meaning 'pillars or central themes' in Māori language). The three central pou are: (1) antimicrobial resistance, (2) freshwater quality, and (3) emerging infectious diseases.

Interwoven through these three pou are three cross-cutting themes, to which all projects need to respond. The first is Vision Mātauranga, a Government science policy that aims to 'unlock the innovation potential of Māori knowledge, resources and people for the benefit of Aotearoa-New Zealand.' [36] Vision Mātauranga is an important and integral cross-cutting component, guiding and contributing relevant research in all three central pou. The other cross-cutting themes are: (2) climate change and ecosystem disruption, and (3) achieving policy change, which includes One Health metrics, modelling and policy. These cross-cutting themes respond to the need to address globally important, human-made ecosystem threats within and across the main pou, and the need to carry out research on robust measures of impact and to identify ways for policymakers to make effective change.

Although New Zealand has low rates of antimicrobial resistance, the prevalence is growing [20,37,38] and the reasons for this increase, including sources and pathways of transmission, need to be understood [39–41]. Recent analyses show that antimicrobial use in animals is relatively low compared to other food trading countries in Europe, Australia, Canada, and USA [19], whereas human use is relatively high [42]. The New Zealand veterinary profession has set an aspirational goal to further reduce the use of antibiotics in animals, and phase out reliance on antimicrobials for the maintenance of animal health and welfare by 2030 [19].

Freshwater quality in New Zealand is declining, a trend closely tied to agricultural intensification [20,38]. Greater understanding about points of contact and transmission of potential pathogens between animals, humans, and waterways is urgently needed. The importance of a One Health approach to this issue was demonstrated in 2016 with the massive outbreak of gastroenteritis in the town of Havelock North. The outbreak, one of the world's largest reported waterborne outbreaks, was traced to sheep faeces contaminating bores supplying drinking water [43]. OHA researchers were at the forefront of the investigation and control of this outbreak.

The emergence and re-emergence of infectious diseases frequently require responses from multiple disciplines. Recent examples include leptospirosis [44], murine typhus [45], *Mycoplasma bovis* infection [46], *Salmonella enterica* Serovar Typhimurium DT160 infection [47], *E. coli* O157:H7 infection [48], and pandemic influenza [49]. These diseases have multiple pathways of entry. For example, S. Typhimurium DT160 was linked to wild birds, pandemic influenza was introduced by human travellers, and *M. bovis* was most likely brought in by material from cattle [46]. Concerns about the potential to introduce mosquito-borne and other diseases not currently established in New Zealand are real [50]. Understanding external drivers of imported infectious diseases is essential for informing biosecurity measures and pandemic preparedness [51]. New Zealand's relative isolation may also provide opportunities to consider disease prevention options that are not available to larger, more connected geographical regions [52].

Conclusion

New Zealand's isolation, small population, unique natural environment, and growing aspiration for a healthy, well-managed and sustainable physical, economic, and social environment, makes it an excellent example of where a One Health approach makes sense, and where its scientific community can build a cohesive national-level alliance of researchers. Greater involvement and overlap of the environmental sciences, human and animal health sciences, social sciences, and indigenous kaupapa Māori-led research is critical for ensuring its success within the New Zealand context.

OHA has made great headway in breaking down traditional silos and better connecting with stakeholders and policy-makers. Despite an encouraging start, OHA still has a way to go to achieve its aspirational goals. The alliance must ensure it draws on a full range of relevant disciplines, knowledge systems, professional groups and community networks. The value of a One Health alliance is becoming increasingly recognised to researchers working within narrow subject areas as they grapple with a growing myriad of health, environmental and sustainability challenges. These challenges demand new ways of collaboration across boundaries and knowledges to define research priorities and find solutions that can achieve outcomes locally, nationally and internationally.

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Abstract

Glass ceilings in New Zealand universities:
Inequities in Māori and Pacific promotions and earnings

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Māori and Pacific academics make up less than 4% and 1%, respectively, of New Zealand professors.

The authors investigated ethnic inequities in promotions and earnings in New Zealand universities. Using data from New Zealand's Performance-Based Research Fund (PBRF) (2003, 2012, 2018) they found that Māori and Pacific men and also women academics, compared with non-Māori non-Pacific men academics, had significantly lower odds of being an associate professor or professor (professoriate) or of being promoted, and had lower earnings. These inequities were not explained by research performance (measured by PBRF scores), age, or field, and remained over time, particularly for women. Māori and Pacific women academics earned on average $7,713 less in 2018 than non-Māori non-Pacific men academics and had 65% lower odds of being promoted into the professoriate from 2003 to 2018. The authors' findings suggest that current inequities for Māori and Pacific academics will persist without systemic change in New Zealand universities.

MAI Journal vol 9(3), 2020, p. 272–85.
DOI: 10.20507/MAIJournal.2020.9.3.8

www.journal.mai.ac.nz/content/glass-ceilings-new-zealand-universities-inequities-māori-and-pacific-promotions-and-earnings

Book description

Science for Policy Handbook

Vladimir Šucha and Marta Sienkiewicz (Editors)

Science for Policy Handbook provides advice on how to bring science to the attention of policymakers. The handbook is dedicated to researchers and research organisations aiming to achieve policy impact.

The Joint Research Centre (JRC) is the European Commission's science and knowledge service, with a mission to bring science and knowledge into EU policymaking. Over the past years, it has embraced new types of knowledge and practices in order to increase the impact of research on European policies. The Handbook presents the lessons learnt along the way, applicable not just in the EU context.

The book puts together advice on new skills and practices for individual researchers, but also discusses elements of institutional change – knowledge areas and processes in which to invest. It puts co-creation at the centre of Science for Policy 2.0, a more integrated model of knowledge-policy relationship.

Key Features

- Covers the vital area of science for policymaking
- Includes contributions from leading practitioners from the Joint Research Centre/European Commission
- Based around key skills for practitioners at the science-policy interface, needed for effective evidence-informed policymaking
- Presents processes of knowledge production relevant for a more holistic science-policy relationship, as well as particularly sought after types of knowledge useful in policymaking

<u>About the book</u>

Published: 2020

This Open Access book is sponsored by the European Joint Research Centre

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News

Hazards defined and classified to strengthen disaster risk reduction

The world is faced by a broad range of complex hazards, whether they are due to natural or environmental phenomena, human interventions, or societal challenges. However, the lack of common definitions for such hazards can hamper effective monitoring of disaster risk reduction efforts.

Recognizing this challenge, The International Science Council[1] partnered with the United Nations Office for Disaster Risk Reduction (UNDRR) in 2019 to launch a science project to identify the full scope of all hazards relevant to the Sendai Framework[2] and the scientific definitions of these hazards. The outcome of the project was *The Hazard Definition & Classification Review: Technical Report*[3], which targets the following 6 recommendations.

Recommendation 1: Regular review and update of a standard set of classifications of hazards, and the development of an agreed process of identifying and defining hazards for risk-based decision-making and action

Recommendation 2: Facilitate the development of a multi-hazard information system. The next step should be the continuing development of hazard definitions as online resources, encoded following linked-data and open-science best practices through a meta-data approach.

Recommendation 3: Engaging with users and sectors for greater alignment and consistency of hazard definitions. Engagement with a range of users working in disaster risk reduction, emergency management, climate change, and increasingly sectoral actors pursuing sustainable development is needed to further develop hazard definitions.

Recommendation 4: Use this hazard list to actively engage policymakers and scientists in evidence-based national risk assessment processes, disaster risk reduction and risk-informed sustainable development, and other actions aimed at managing risks of emergencies and disasters.

Recommendation 5: Conduct further work to operationalise parameters for exposure, vulnerability and capacity, building on the existing UN General Assembly definitions, a much needed complementary exercise to the hazard definition process.

Recommendation 6: Address cascading and complex hazards and risks. There is an urgent need to investigate further the direct and indirect linkages and effects of natural, biological, technological and other human-induced hazards to identify better and understand cascading and complex hazards and risks in a systematic way.

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[1]https://council.science/

[2]https://www.undrr.org/implementing-sendai-framework/what-sendai-framework

[3]https://council.science/publications/hazards/?utm_source=ISC+Newsletter&utm_campaign=916e52196c-&utm_medium=email&utm_term=0_6e20810dfd-916e52196c-34368581

News

How we kill creativity in New Zealand schools

Our education system effectively stifles children's natural curiosity about the world, according to a new report from the University of Auckland.

The Centre for Arts and Social Transformation at the University of Auckland's Faculty of Education and Social Work has released its first report on the state of creativity in New Zealand schools, *Replanting Creativity: During Post-Normal Times.*

Based on four years of work, the quantitative study measures eleven dimensions of what makes a creative environment in primary and secondary schools. Across all school levels, children have declining opportunities to play with ideas, the report concludes.

As children progress through school there are fewer chances for collaboration, for working outside or across discipline boundaries, and for taking risks and problem solving. The end result is that schooling fails to create the kind of citizens we so urgently need to succeed in the post-normal world we live in, the report says.

Professor Peter O'Connor, who led the research, believes the results confirm the suspicion that decades of neglect of the arts in New Zealand schools has stripped life and colour from our schools.

'The arts and creativity have disappeared from schools as part of deliberate government policies for decades and this has serious implications for the future of work, democratic citizenship and for student well-being.'

He sees this as a systemic failing brought about by decades of focus on literacy and numeracy at the expense of everything else schools could and should do.

The full report can now be accessed at:
https://www.teritotoi.org/replanting-creativity-during-post-normal-times/

scientists.org.nz
The New Zealand Association of Scientists
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Public Statement

Scientific Society Presidents Call for Ministerial Intervention in Massey Science Cuts

The Presidents and Past Presidents of seven of New Zealand's scientific societies have released an open letter calling for incoming Ministers to intervene in Massey University's proposal to cut one third of science staff.

The letter's release coincides with the closing day of Massey's consultation on the cuts, and a last chance for reconsideration using standard academic processes within the university.

The letter states, 'The sheer magnitude of change, its lack of clear definition, and intended purpose stand in stark contrast to the legislative definition of a university.'

President of the New Zealand Association of Scientists, University of Waikato Professor Troy Baisden, says 'Massey's proposal and processes undermine all five elements defining a university under the New Zealand legislation.'

The letter states, 'The consequence for institutions that do not act in accordance with their legislation must be ministerial intervention. We agree that the threshold for Ministerial intervention is indeed very high, but find clearly that it has been crossed. '

In determining that the cuts are nationally significant, the presidents of the scientific bodies also note that the executive of the public university is acting with less accountability than a publicly traded corporation.

'Unless Massey University undertakes immediate remediation of its processes as we request, we call on the Minister of Tertiary Education and the Minister of Research Science and Technology to urgently rein in the pace of decision-making at Massey University and install an appropriate independent review mechanism.'

The open letter is available at: http://bit.ly/MasseyCuts

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Join the Association!

The New Zealand Association of Scientists (NZAS) is an independent body that stands for and advocates for science and scientists in New Zealand.

We are made up of a wide cross-section of the New Zealand science community, from University departments to CRIs to those working in independent research organisations or in science-related policy development who work and lobby to:

- promote science in New Zealand,
- increase public awareness of science and expose pseudo-science,
- debate and influence government science policy,
- improve working conditions for scientists, including gender and ethnic equality,
- promote free exchange of knowledge and international co-operation, and
- encourage excellence in science.

The Association membership includes physical, natural, mathematical and social scientists and welcomes members with an interest in science education, policy, communication and the social impact of science and technology.

Go to: https://scientists.org.nz/membership

NZAS
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Why not consider joining NZAS?

Members include physical, natural, mathematical and social scientists, and the Association welcomes anyone with an interest in science education, policy, communication, and the social impact of science and technology.

Please complete this form and return it with payment to:
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NZAS is an independent organisation working to:

- Promote science for the good of all New Zealanders
- Increase public awareness of science
- Debate and influence government science policy
- Promote free exchange of knowledge
- Advance international co-operation, and
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Member Benefits:

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